SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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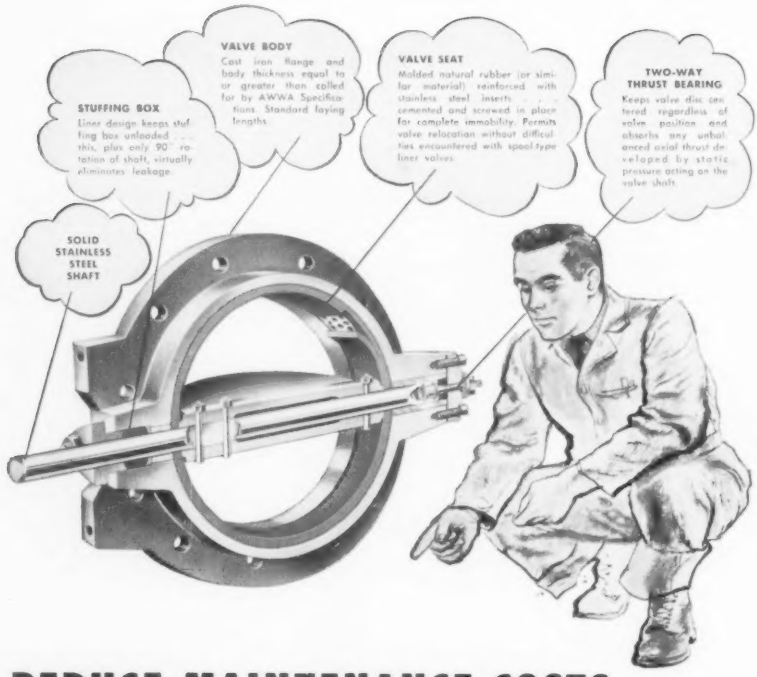
AUGUST, 1957—VOL. 29, No. 8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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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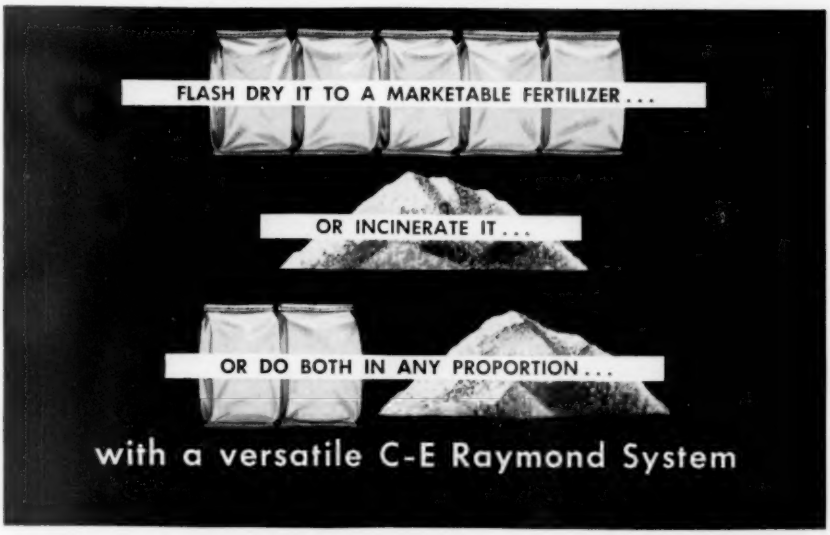
Dispose of Sewage Sludge the Modern Way



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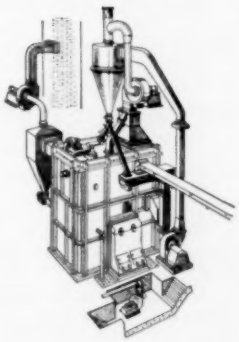

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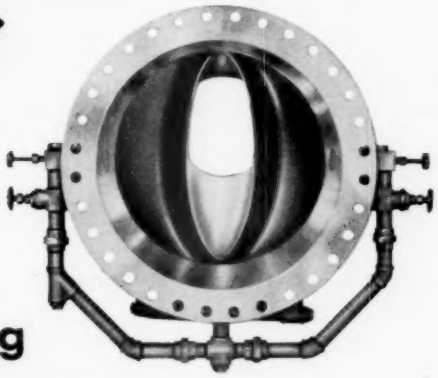

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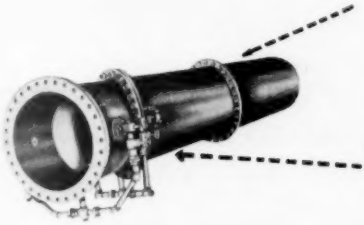

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Association	*Place*	*Time*
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South Dakota Water and Sewage Works Conf.	Sheraton Cataract Hotel Sioux Falls, So. Dak.	Sept. 11–13, 1957
Abwassertechnische Vereinigung (Germany)	Bremen, Germany	Sept. 18–20, 1957
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Brown Hotel Louisville, Ky.	Sept. 23–25, 1957
Rocky Mountain Sewage and Industrial Wastes Assn.	LaFonda Hotel Santa Fe, N. Mex.	Sept. 23, 1957
Oklahoma Water, Sewage and Industrial Wastes Conf. (Ind. Wastes)	A. & M. College Stillwater, Okla.	Sept. 25–26, 1957
North Dakota Water and Sewage Works Conf.	Gardner Hotel Fargo, No. Dak.	Sept. 25–27, 1957
Georgia Water and Sewage Assn.	Georgia Inst. of Technology Atlanta, Ga.	Sept. 25–27, 1957
Missouri Water and Sewerage Conf.	Hotel Sheraton Jefferson St. Louis, Mo.	Sept. 29–Oct. 1, 1957

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in conjunction with
New England Sewage and Industrial Wastes Association
Statler Hotel, Boston, Massachusetts
October 7–10, 1957

West Virginia Sewage and Industrial Wastes Assn.	Hotel McClure Wheeling, W. Va.	Oct. 24–25, 1957
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Canadian Inst. on Sewage and Sanitation	King Edward Hotel Toronto, Ont., Can.	Oct. 28–30, 1957
Nebraska Sewage and Industrial Wastes Assn.	Clark Hotel Hastings, Nebr.	Nov. 7–8, 1957
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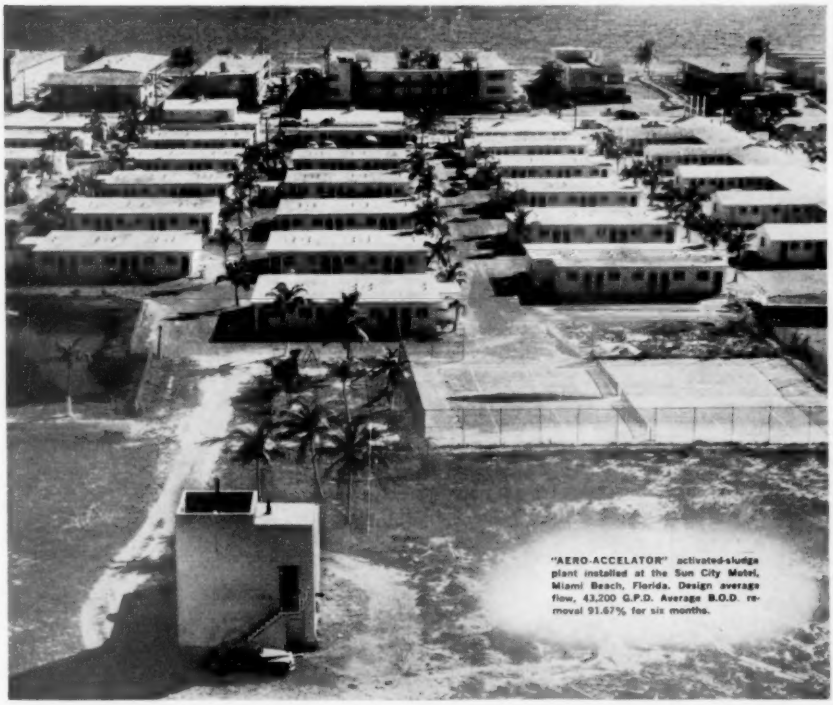

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90-95% B.O.D. REMOVAL IN LITTLE SPACE AT LOW COST

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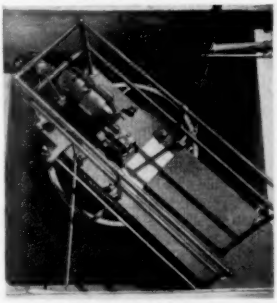
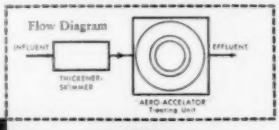
Performance is excellent. Here are the figures —

Month	Ave. Flow M.G.D.	B.O.D.P.P.M.			Suspended Solids — P.P.M.		
		Raw Sewage	"AERO-ACCELATOR" Effluent	% Removal	Raw Sewage	"AERO-ACCELATOR" Effluent	% Removal
Jan.	.006	187	9.5	94	239	24	90
Feb.	.010	157	13.0	92	409	32	92
Mar.	.005	137	7.0	95	383	28	93
Apr.	.006	211	25.0	88	328	36	89
May	.006	171	8.0	94	222	5	97
June	.008	173	8.0	95	295	32	89



"AERO-ACCELATOR" unit



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Inquiries and samples are invited on all problems in the treatment of waters, sewage and wastes. Write today for the "AERO-ACCELATOR" activated sludge plant bulletin, No. 6510.

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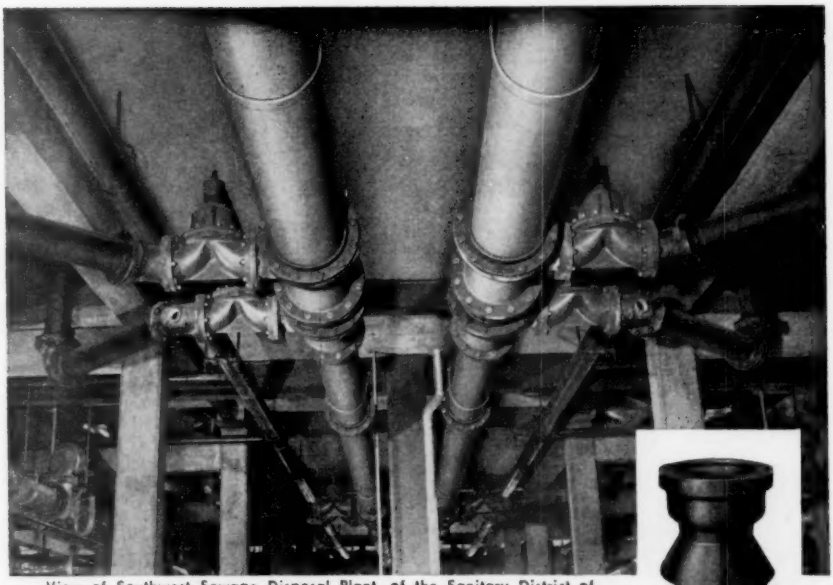

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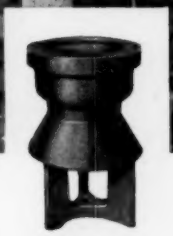

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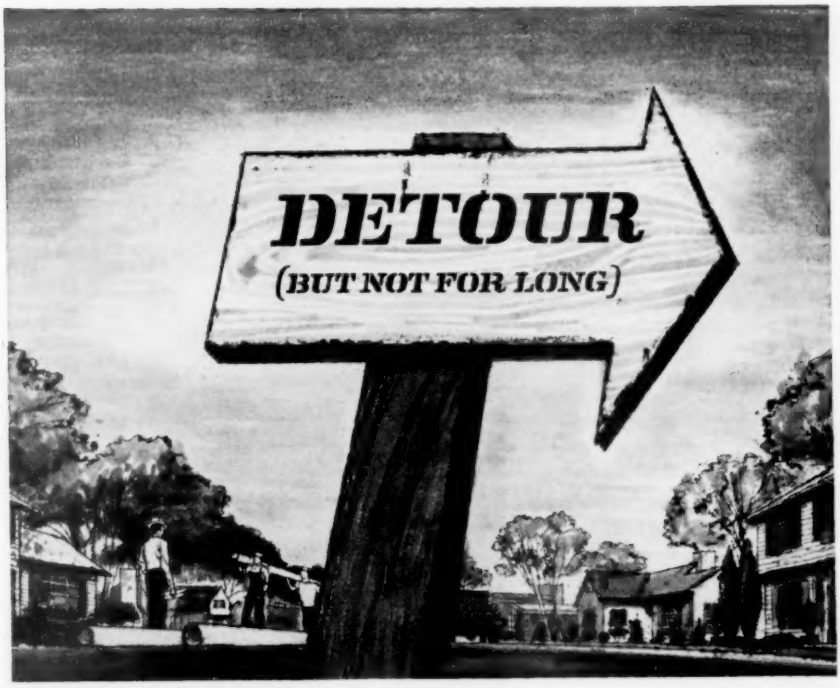

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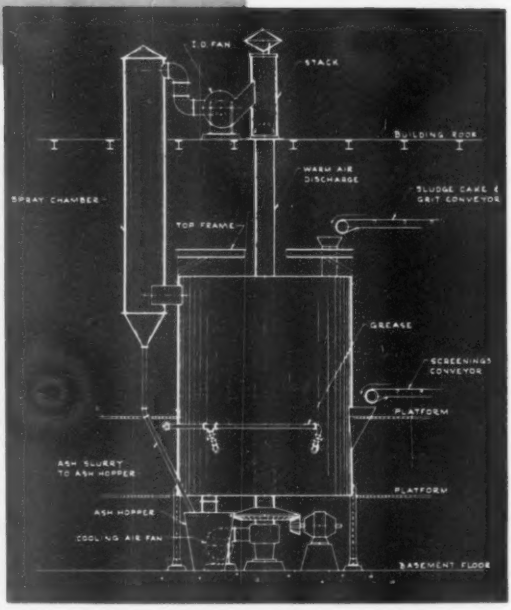

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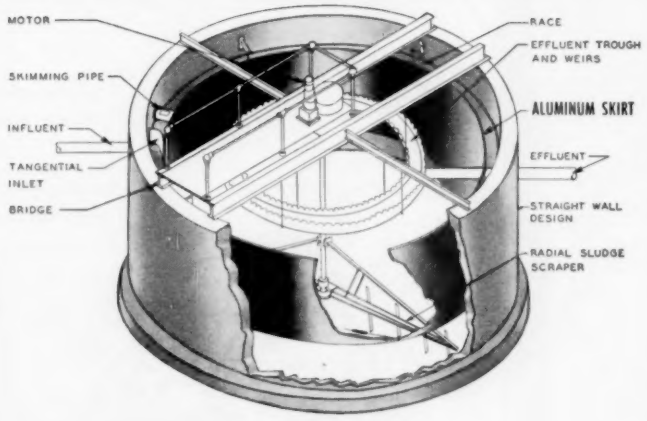

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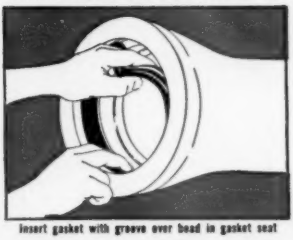
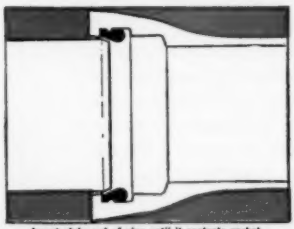
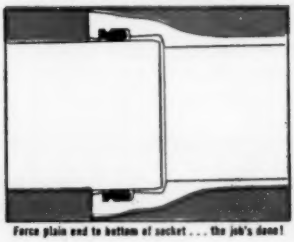


Insert gasket with groove over bead in gasket seat

Wipe a film of special lubricant over inside of gasket



Insert plain end of pipe until it contacts gasket



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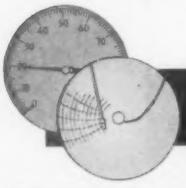

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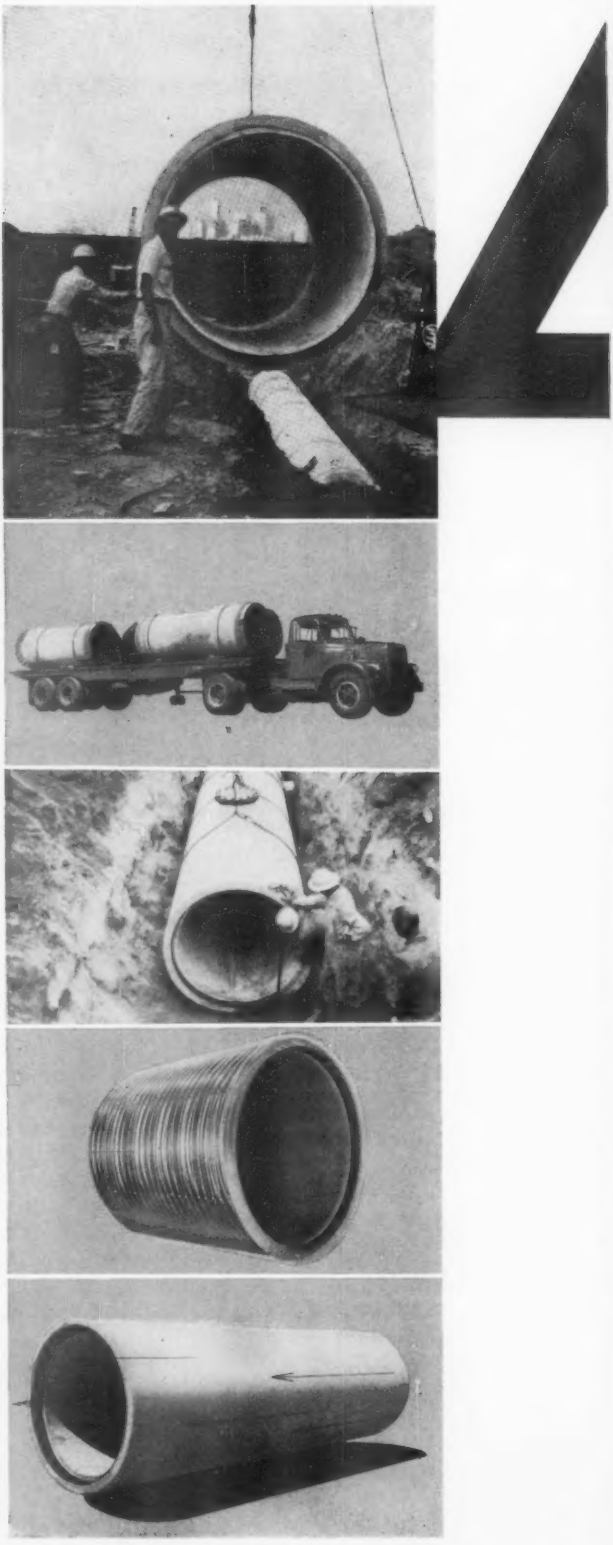

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 29 | August, 1957 | Number 8

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Sewage Works

CONTACT AERATION SEWAGE TREATMENT PLANTS IN NEW JERSEY *

By John Wilford and Thomas P. Conlon

Senior Public Health Engineers, Bureau of Public Health Engineering, Division of Environmental Sanitation, New Jersey State Department of Health, Trenton, N. J.

The era of the so-called "package plant" in the field of sewage treatment gained momentum in New Jersey about seven years ago. It was given its greatest impetus by the promoters of small contact aeration plants, at that time proposed primarily for realty developments of a few hundred houses.

Engineers of the New Jersey State Department of Health studied the available literature on the subject and observed a wide variance of opinion as to the acceptance of contact aeration by the sanitary engineering profession. It was concluded that approval for their use should be granted, subject to the Department's usual performance requirements as to effluent quality.

It was reasoned that the contact aeration plants being offered at that time were economically acceptable to the booming housing industry. Even with only a 50 per cent efficiency, these plants would obviate the public health menace of septic tanks so inadequate in housing developments in New Jersey. It was believed, however, that a much better efficiency would be obtained.

The authors conducted a survey and studies for two purposes: (a) to evaluate the contact aeration treatment method, and (b) to collect data as to the basis for the drafting of rules and regulations to control the design of contact aeration sewage treatment plants.

History

Although it is 18 years since the first municipal contact aeration type sewage disposal plant was constructed at Elgin, Texas, no installations of this type had been constructed in the State of New Jersey prior to 1951.

The contact aeration process was developed and patented by Clyde C. Hays of Waco, Texas. Further mechanical improvements were incorporated into the process by L. B. Griffith of Washington, D. C., who was associated with Hays in the early stages of development. Early plants made use of aerated submerged rock filters called "Hays Process Filters," and the plants were often referred to as the "Submerged Contact Aeration Process." These plants comprised a preliminary settling tank, first-stage submerged rock filter, intermediate settling tank, second-stage submerged rock filter, and a final settling tank. The concept of utilizing two stages of biological treatment was an innovation which at first did not receive general approval. In the original plants the six tanks were individual units located some distance apart. Each was provided with sludge hoppers from which sludge was first pumped to a well, thence to a conventional sludge digester.

* Presented at the 1957 Annual Meeting, New Jersey Sewage and Industrial Wastes Assn.; Atlantic City, N. J.; Mar. 13–15, 1957.

Within the next few years many improvements were effected. One of the most important of these was propounded by H. B. Schulhoff, who proposed the use of a series of flat panels in place of the rock medium formerly used in the submerged filters. The sewage was kept in motion by perforated air diffuser pipes. This action brought the sewage in contact repeatedly with a biological growth which formed on the panels, whereas in the earlier rock filters it passed through the medium only once. In 1940, the first monolithic submerged filter plant was developed in which the five separate treatment tanks and sludge digester were of common wall design. Later modifications included a more efficient air diffuser system using carborundum tubes, automatic timers for the operation of sludge lifts, and other equipment.

The data on which this paper is based apply exclusively to the type of contact aeration known as the "Griffith Contact Aeration Sewage Treatment Plant." Although both Hayes and Griffith have approved minor modifications in plants constructed under their respective licenses, the basic process is identical in plants of either designation. Today there are 27 contact aeration plants in operation in New Jersey and four others under construction.

Plant Description

The contact aeration sewage treatment plants in the State of New Jersey are of similar construction varying only in size according to the design flow. The basic treatment units consist of five open tanks of monolithic construction, a sludge digester and sludge drying beds. The flow diagram (Figure 1) shows that the raw sewage passes successively by gravity through a preliminary settling tank, first-stage aeration tank, intermediate settling tank, second-stage aeration tank, and final settling tank. The preliminary settling tank may be either of flat-bottomed construction equipped with a mechanical sludge collecting mechanism or hopper-bottomed, dependent on the size of the unit. Each of the

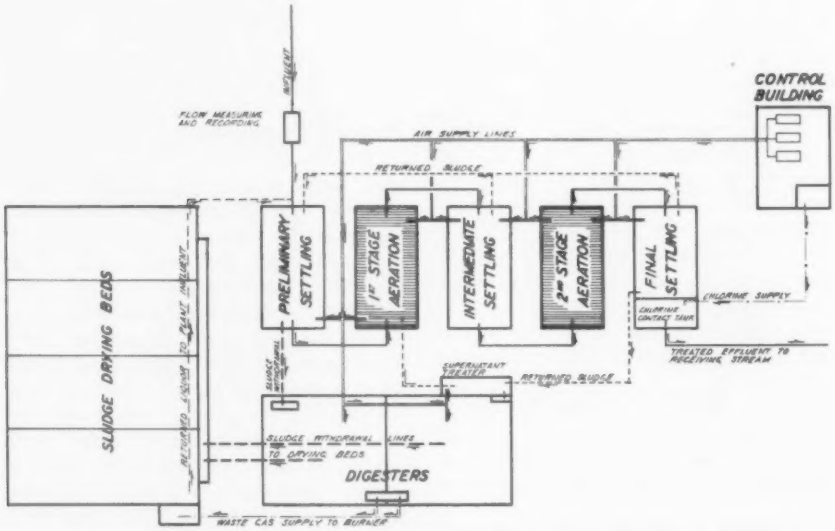

FIGURE 1.—Flow diagram of a typical submerged contact aeration sewage treatment plant.

other tanks has a hopper bottom. Standard effective water depth of each tank is usually 9.5 ft., exclusive of the hoppers.

Sludge from the aeration tanks and the intermediate and final settling tanks is returned to the raw sewage channel, while the digester receives only sludge from the preliminary settling tank. The detention period at design flow in the preliminary settling tank is 2.5 hr. The other four tanks each provide 1.5 hr. of detention, giving a total detention time of 8.5 hr.

Aeration Tanks

In the aeration units, asbestos cement panels are suspended vertically to a depth of 8 ft. They are ¼ in. thick and are spaced 1½ in. on centers. These plates form the media on which the biological growth adheres. The plates also form a system of baffles which causes the sewage to pass up and down between the plates in repeated contact with the biological growth. This movement is further accelerated by the air issuing from the diffuser tubes suspended below the bottoms of the plates. It is not necessary to remove, clean, or care for the plates in any manner, nor has it been found necessary to remove any of the diffuser tubes.

The first- and second-stage aeration units are identical in construction. The design of the present New Jersey plants is based on an average sewage flow of 100 g.p.c.d., and an assumed average B.O.D. strength of 200 p.p.m. For each 8 lb. of the total daily B.O.D. load, 1,000 sq. ft. of contact plate area is provided. A 40 per cent removal of B.O.D. by the preliminary settling tank is assumed, leaving a theoretical net B.O.D. load of 5 lb. per 1,000 sq. ft. of contact plate area per day to be applied to the two aeration units. Due to the standard size and spacing of the contact plates it is this loading which determines the required size of the two aeration tanks and bears a direct relationship to the standard detention period of 1.5 hr. for each unit.

Air Supply

The combined air supply to the two stages of aeration is based on a minimum of 1.5 cu. ft. of air per gallon of sewage. The available air is usually proportioned so that 60 per cent is supplied to the first-stage aeration tank with the remaining 40 per cent supplied to the second-stage aeration tank. The air is delivered by two blowers, each of which is capable of providing the entire required air flow. A series of 4-in. diameter porous diffuser tubes is used.

The blowers also supply air for all the ordinary pumping requirements throughout the plant. A system of vertical air lifts is used to lift sludge from the various treatment units, to draw digested sludge and supernatant liquor from the digester, and to remove scum from the surface of the preliminary settling tanks.

The control of these air lifts is usually automatic; their operation at predetermined times for set periods is effected by a series of timers which activate solenoid valves. The sludge from the preliminary settling tank is lifted to the digester in one continuous operation, but sludge from the other units is usually removed by a 7-sec. on-off sequence of the air lifts during the over-all operating period. The operation of both blowers is also controlled by solenoids and in the event of a breakdown of the blower being used, the other one will start up automatically. Provision is also made for the manual control of the various units.

Chlorination

Chlorine is applied to the sewage as it enters the final settling tank. This unit affords a chlorine contact period of 1.5 hr. at design flow, which complies with the requirements of the New Jersey State Department of Health. As most of the suspended solids are

removed from the sewage in the preceding tanks no difficulties have been experienced in maintaining a satisfactory chlorine residual.

Layout

The small contact aeration plants are of single-unit construction, but the large ones consist of two identical complete treatment units located side-by-side and each receives approximately one-half of the total sewage flow. As these are interconnected, great flexibility of operation is possible and any unit may be by-passed without materially reducing the degree of treatment. Due to the simple physical layout of these plants, it is a relatively easy matter to construct an additional unit to accommodate increased flows of sewage. There is no limit to the ultimate capacity of an installation.

Operation

Although the operation of a contact aeration sewage treatment plant is simple and a number of automatic devices are used, it should not be assumed that automation has entirely replaced manpower. The plant must be cared for periodically and a full-time operator is necessary for the large installations.

Daily routine duties include (a) the cleaning of the bar screens or rag catchers, (b) the inspection of the sludges from the various tanks, (c) the adjustment of the air distribution system, (d) the squeegeeing of the various settling tanks, (e) the inspection and adjustment of chlorination equipment, and (f) the completion of the various tests and record data required by the New Jersey State Department of Health. Additional periodic duties include the "blowing" of the aeration diffuser tubes, the drying of digested sludge, and the inspection and/or servicing of the air blowers, air blower filters, motors, air pressure, automatic clocks, and chlorine supply.

Despite the velocity of the air through the porous diffusers a film of the biological growth gradually forms on them, causing a diminished air supply and a slight increase of pressure in the air ducts. It is to remove this film that the tubes are periodically "blown." The operation of "blowing" the tubes consists of turning off the air supply to all main diffuser headers except one and permitting the full air supply to blow through the appropriate diffusers at a high velocity for about 20 min. This is done to each bank of diffusers in turn.

Froth Control

As might be expected, the presence of large amounts of synthetic detergents in the sewage causes the production of froth in the aeration tanks. Two methods of combatting this nuisance have been practiced, namely: the constant addition of a few drops per minute of a commercial antifroth agent, or the provision of sprays in the aeration tanks. The liquid used in the sprays is obtained by utilizing sewage recirculated from the final settling tank or by pumping sewage direct from the aeration tanks.

Although both methods are effective in performing the required purpose, the oil base of the commercial antifroth agents renders the plant unsightly, adds to the operating maintenance by adhering in a sticky mass to the sides of the tanks and to the upper surfaces of the contact aeration plates. Experience indicates that they interfere with sludge digestion.

Biological Growth

When a new plant is placed in operation an overdose of air is applied to the aeration tanks for the first few weeks and a prolific growth of biological floc rapidly builds up on both sides of each contact plate. It is most rapid during the summer.

The floc is of a semigelatinous consistency, similar to that found on the media of a conventional sprinkling filter. Near the surface of the tanks it

may be grey in color, grey-green, green, brown, pink, or even maroon, according to the types of algae and bacteria present. At the lower depths it is invariably grey or brown.

On the upper surfaces of the plates the growth usually increases until it reaches a thickness of about ½ in.; it is more sparse at deeper levels. As the depth of the sewage increases the growth tapers off until, at the 8-ft. level, it is practically nonexistent.

When the growth reaches the optimum thickness it sloughs off the plates in minute particles which settle out in the intermediate or final settling tanks and are returned to the incoming sewage. This sloughing action is constant to a greater or lesser degree, but (as in a sprinkling filter) it is more marked during climatical changes, such as are experienced in the spring and fall. This may account for the occasional slight increase of suspended solids and B.O.D. found in the effluents sampled from the aeration tanks.

Limnology

Samples of the floc were taken from near the surface of each aeration tank at each of the plants investigated. Slides were prepared and examined microscopically. In general, the samples were collected during the summer and fall, but additional tests were made at a few selected plants during the winter.

Large volumes of plankton including fungi and algal forms of both the green and red types, diatoms, and various types of bacteria were observed but no attempt was made to classify them. Several forms of protozoa were present including *Sarcodina*, *Mastigophera*, *Infusoria*, rotifers and nematodes.

In evaluating the presence of the different types of protozoa no effort was made to list them numerically or on a percentage basis as such would be misleading and would bear no correlation to the efficiency of the sewage treatment.

Confirming the observations of McKinney and Gram (1), it was apparent that the *Infusoria* are the key protozoa in the degree of treatment and any evaluation of the efficiency of sewage treatment must include the relation of these organisms with other types of protozoa present.

In general it was observed that, in plants where the percentage removal of B.O.D. by the units was highest, the free-swimming ciliates were present with a relatively high proportion of stalked ciliates and a lesser number of flagellated *Mastigophera*. Conversely, in plants demonstrating less efficient B.O.D. removal the stalked ciliates were few or absent and larger numbers of *Mastigophera* were present (2). Rotifers were more prevalent in the plants demonstrating greatest efficiency. Amoeba and nematodes were observed in samples from several plants with differing B.O.D. removal efficiencies, but in no case were the amoeba numerous.

Except for the thickness of the floc, which was observed to diminish from ½ in. at the surface to merely a thin film at the 8-ft. level, there was no appreciable difference in the types and proportionate distribution of protozoa found at 2-ft. intervals of depth. No changes in the types or relative numbers of organisms were observed in winter, except that during periods of near-zero weather there was a complete absence of protozoa in the growths taken from the upper 12 in. of the contact plates. At the lower depths the protozoa were more sluggish in movement.

When one plant was operated with a diminished air supply (less than 0.9 cu. ft. of air per gallon of sewage) for several weeks, the 8-ft. sample tubes suspended in the aeration tank were clean of biological growth. This demonstrated the minimum air requirement for the growth of protozoa. The

TABLE I.—Flows and Detention Periods During Sampling

Plant	Year Built	Flow					Detention Period (hr.)											
			Present Average		During Sampling		At Design Flow						At Flow During Sampling					
		Design (m.g.d.)	(m.g.d.)	Design (%)	(gal./hr.)	Design (%)	Pre-settling	1st Aerator	Inter. Settling	2nd Aerator	Final Settling	Total	Pre-settling	1st Aerator	Inter. Settling	2nd Aerator	Final Settling	Total
Bossert Estates	1953	0.12	0.066	55	2,960	59	2.66	1.5	1.52	1.5	1.52	8.7	4.51	2.52	2.56	2.52	2.56	14.67
Cooper Village	1956	0.10	0.02	20	1,160	27.8	2.54	1.5	1.69	1.5	1.69	8.92	9.2	5.42	6.1	5.42	6.1	32.24
Greenfield Village	1953	0.10	0.15	150	5,542	135	2.65	1.75	1.94	1.7	1.70	9.74	2.0	1.3	1.4	1.2	1.2	7.3
Pemberton	1954	0.18	0.1	55.6	4,100	54.7	2.46	1.53	1.58	1.53	1.58	8.8	4.49	2.8	2.88	2.8	2.88	15.85
Runnemede Unit No. 1	1953	0.4	0.15	37.5	11,136	66.8	2.5	1.5	1.8	1.5	1.8	9.1	3.75	2.25	2.6	2.25	2.6	13.45
Runnemede Unit No. 2	1953	0.4	0.326	81.5	15,310	91.8	2.5	1.5	1.8	1.5	1.8	9.1	2.74	1.66	1.91	1.66	1.91	9.88
Shore Crest	1956	0.12	0.10	83.5	4,830	96.8	2.56	1.52	1.73	1.52	1.73	9.06	2.64	1.57	1.78	1.57	1.78	9.34
Swedesboro Unit No. 1	1953	0.174	0.067	38.3	2,900	40	2.51	1.49	1.53	1.49	1.53	8.55	6.35	3.75	3.76	3.75	3.76	21.37
Swedesboro Unit No. 2	1953	0.174	0.083	47.7	5,162	71	2.51	1.49	1.53	1.49	1.53	8.55	3.55	2.10	2.17	2.10	2.17	12.09
Woodbury Heights Test No. 1	1955	0.1	0.065	65	4,200	100	2.6	1.5	1.5	1.5	1.5	8.6	2.6	1.5	1.5	1.5	1.5	8.6
Woodbury Heights Test No. 2	1955	0.1	0.116	116	7,650	183.6	2.6	1.5	1.5	1.5	1.5	8.6	1.43	0.82	0.82	0.82	0.82	4.73

original growth on the contact plates became extremely gelatinous and there was a complete absence of protozoal life. Conversely, when the air supply was increased to an excess, free-swimming ciliates and large numbers of stalked ciliates appeared. However, *Sarcodina* and *Mastigophora* were absent.

Sampling Data

Selection of a representative cross section of treatment plants for sampling purposes was somewhat difficult. All the plants were constructed since 1951 and most were serving housing developments still being built. Of those serving municipalities, few had reached the basic design flow. Exceptions were those at the Borough of Woodbury Heights, where the contact aeration type plant had replaced the original installation, and at Greenfields Village where the number of houses built had greatly exceeded initial planning.

Eight plants were selected for routine sampling (Table I). In general these were receiving the greatest average flows as compared with design flows, but the plant at Cooper Village, receiving only 20 per cent of design flow, was also included to serve as a basis for comparison. Two municipal plants (Woodbury Heights and Swedesboro) were visited after excessive rainfall, to observe the effect of the extensive infiltration experienced at these plants. Advantage was also taken of the twin units at Runnemede to divert all the incoming sewage through one unit.

A sampling period was chosen for each plant to ensure that the effect of the full daytime load was obtained, thus minimizing the effect of low night flows. In most cases the sampling period extended over 6 hr., although on occasion an 8-hr. period was used. Separate catch samples were taken hourly for dissolved oxygen and B.O.D. determinations on the raw sewage and the effluents from the preliminary settling tank, first-aeration tank, intermediate settling tank, second-aeration tank, and final settling tank. Composite samples for chemical analysis were also collected at the same points. The appropriate analyses were made utilizing procedures as outlined in *Standard Methods*.

Suspended Solids, Loading and Efficiencies

Table II presents data on the suspended solids loading and the performance efficiency of each of the units in the eight plants covered by this study.

In general, the over-all removal was good with better than 90 per cent efficiency in 5 of the 11 tests. With the exception of Greenfields Village, which had an overload of sewage flow combined with a defective solenoid valve to the sludge air lifts, and Shore Crest which had recently been placed in operation, the remaining tests showed better than 80 per cent efficiency.

As would be expected, the preliminary settling tank removed most of the suspended solids. Except at Greenfields Village and at Woodbury Heights Test No. 2, which was affected by excessive infiltration, removals of 40 per cent and greater were achieved in this tank.

It may also be noted that on several occasions the aeration tanks added suspended solids to the sewage. This may be attributed to the normal sloughing action of the growth on the plates.

B.O.D. Loading and Efficiency

The B.O.D. loading and performance of the plants studied during this survey are summarized in Table III.

An average raw sewage B.O.D. content of 200 p.p.m. has long been accepted by both designing engineers and state health departments, but evidence would indicate that this is somewhat

TABLE II.—Suspended Solids Loading and Performance

Plant	Design Flow (%)	Suspended Solids (p.p.m.)						Removal (%)					
		Influent	Pre-settling	1st Aerator	Inter. Settling	2nd Aerator	Final Settling	Pre-settling	1st Aerator	Inter. Settling	2nd Aerator	Final Settling	Overall Removal
Bossert Estates	59	395	99	112	74	59	36	75	+13	34	34	39	91
Cooper Village	28	724	80	29	10	15	5	89	64	66	+50	67	99
Greenfield Village*	135	174	112	45	62	17	46	36	60	+38	73	+171	74
Pemberton	55	215	81	84	20	14	10	62	+4	76	30	29	95
Runnemede Unit No. 1	67	226	94	75	23	18	3	58	20	69	22	83	99
Runnemede Unit No. 2	92	263	96	80	81	67	33	64	17	+1	17	51	87
Shore Crest†	97	159	96	79	54	78	35	40	18	32	+44	55	78
Swedesboro Unit No. 1	40	237	129	165	51	87	44	46	+28	69	+71	49	81
Swedesboro Unit No. 2	71	167	81	46	29	11	5	52	43	37	62	55	97
Woodbury Heights Test No. 1	100	200	91	71	50	32	34	55	22	30	36	+6	83
Woodbury Heights Test No. 2‡	184	67	51	45	20	12	8	24	12	56	40	33	88

* Defective solenoid valve to sludge air lifts.

† Plant newly in operation.

‡ Plant overloaded due to excessive infiltration.

low. In only three of the eight plants tested was the B.O.D. of the incoming sewage at or below the usually-accepted value and the average B.O.D. value for all of the plants tested was 251 p.p.m.

The B.O.D. removal in the preliminary settling tanks varied widely. Those at Cooper Village and Runnemede Unit No. 1 were the best, although it should be noted that in each case the average flow was well below design flow. At Runnemede Unit No. 2 with 92 per cent of design flow, Shore Crest with 97 per cent of design flow, and Woodbury Heights Test No. 1 with 100 per cent of design flow, the B.O.D. efficiencies of the preliminary settling tanks were only 22, 30 and 17 per cent, respectively. The average B.O.D. removal for all tests, excluding those at Swedesboro, where the sludge scrapers were not operating, was 28 per cent.

The B.O.D. removal accomplished by the first aeration tanks and their accompanying settling tanks was good. Except for Greenfields Village (overloaded) and Shore Crest (new plant), aerator efficiencies were 53 per cent or greater. Average efficiency for all tests was 64 per cent. It is interesting to note that during the first test at Woodbury Heights the proportionate air supply to the first and second aeration tanks was reversed, the larger amount being distributed to the second aerator. Despite this the first aeration unit showed an efficiency of 63 per cent at design flow. During the second test at this plant the air was proportioned correctly, yielding a B.O.D. efficiency in the first aeration unit of 61 per cent when flow was 184 per cent of design. This would suggest that the actual proportioning of air to the two aeration units is not of great importance as long as the total air supply is adequate, but further investigations would be necessary before any definite conclusions could be drawn.

B.O.D. removal efficiencies of the

TABLE III.—B.O.D. Loading and Performance*

Plant	Design Flow (%)	B.O.D. (p.p.m.)							B.O.D. Applied/ 1,000 sq. ft. of Plate Area/Day† (lb.)	B.O.D. Removal/1,000 sq. ft. of Plate Area/ Day (lb.)			Removal (%)		Remarks
		Influent (p.p.m.)	Preliminary Settling		1st Aerator and Settling Tank		2nd Aerator and Settling Tank			1st Aerator	2nd Aerator	Average	Aerator	Entire Plant	
			Effluent (p.p.m.)	Removal (%)	Effluent (p.p.m.)	Removal (%)	Effluent (p.p.m.)	Removal (%)							
Bossert Estates	59	259	214	17	100	53	47	53	4.6	4.8	2.2	3.5	78	82	
Cooper Village	28	264	113	57	14	87	4	72	1.3	2.3	0.2	1.2	97	98	
Greenfield Village	135	162	136	16	89	35	42	53	7.2	5.0	5.0	5.0	70	74	Overloaded
Pemberton	55	235	199	15	22	88	24	+10	4.1	7.4	0.1	3.7	88	90	
Runnemede Unit No. 1	67	327	156	52	27	83	7	74	4.9	8.3	1.3	4.8	96	98	
Runnemede Unit No. 2	92	403	314	22	130	59	42	68	13.3	15.7	7.5	11.6	87	90	
Shore Crest	97	151	106	30	60	43	26	58	4.9	4.3	3.5	3.9	76	83	New operation
Swedesboro Unit No. 1	40	201	208	+3	63	70	35	45	3.3	4.7	0.9	2.8	86	83	Preliminary settling tank sludge scrapers defective
Swedesboro Unit No. 2	71	204	332	+63	134	60	15	90	9.3	11.2	6.8	9.0	96	93	
Woodbury Heights Test No. 1	100	406	336	17	123	63	42	67	14.2	17.9	6.9	12.4	88	89	Proportionate air supply to aeration tanks reversed
Woodbury Heights Test No. 2	184	147	103	30	39	61	26	33	7.9	9.8	2.0	5.9	75	82	Overloaded due to excessive infiltration

* The aeration unit comprises the aeration tank and the accompanying settling tank.
† Based on average hourly flow during sampling period.

second aeration units were also good. The only exception was at Pemberton where 10 per cent of the B.O.D. was added by this combined unit. However, as the influent to this unit contained only 22 p.p.m. B.O.D., this increase of 2 p.p.m. may be considered negligible.

Combined efficiencies of both aeration units ranged from 70 to 97 per cent. The assumed efficiency of these units is 83 per cent of the applied B.O.D. This efficiency was achieved in 7 of the 11 tests conducted. Of the remaining four plants, two were overloaded, and one was a plant which had been recently placed in operation. The average over-all B.O.D. removal for the 11 tests conducted was 87 per cent.

As mentioned previously, the contact aeration sewage treatment plants discussed here were designed on a daily B.O.D. loading of 5 lb. per 1,000 square feet of contact plate area. This is equivalent to a loading of 10 lb. per 1,000 square feet on the first aeration tank. However, in most instances the incoming sewage had a higher B.O.D. value than the accepted 200 p.p.m. and the B.O.D. removal by the preliminary settling tanks was less than the assumed 35 to 40 per cent. Thus the B.O.D. loading to the aeration units in many cases was in excess of the design load of 5 lb. per 1,000 square feet. Although on a percentage basis the assumed removals were sometimes not achieved, it is important to note that on a poundage basis the aeration units and over-all removal were considerably better than at design.

In 5 of the 11 tests conducted, the loading on the aeration units was greater than the 5 lb. At Runnemede Unit No. 2, with a flow of 92 per cent of design, 13.3 lb. of B.O.D. was applied to each 1,000 square feet of plate area per day, of which 11.6 lb. were removed. At Woodbury Heights, with a flow of 100 per cent of design, 14.2 lb. were applied for each 1,000 square feet, of which 12.4 lb. were removed. It should be noted that at these plants the first aeration units removed 15.7 lb. and 17.9 lb. of B.O.D., respectively, per 1,000 square feet of contact area.

Proposed Modifications

It is believed that new plants of this type will achieve an even greater efficiency due to modifications which have been embodied in plans recently submitted to the New Jersey State Department of Health.

These include the use of horizontal air lifts in place of the present vertical air lifts. This will eliminate hopper tank bottoms. A supernatant treatment unit will be provided. Independent surveys have also demonstrated the higher B.O.D. values of present-day domestic sewage. Future design of aeration units will be based on a raw sewage B.O.D. of 250 p.p.m., instead of the former 200 p.p.m.

Conclusions

The results obtained in this survey would indicate that the contact aeration process is fundamentally sound. It is capable of efficient sewage treatment and, with correct design factors and diligent operation, it can accomplish better than 90 per cent removal of both suspended solids and B.O.D. The survey results establish that the contact aeration process may effect reductions of B.O.D. and suspended solids in excess of those anticipated from design criteria.

The contact aeration method of sewage treatment has proven itself equal to other accepted methods in New Jersey. It has provided an adequate solution of the sewage treatment problem at realty developments and by the use of multiple units show promise for larger installations.

Acknowledgment

Acknowledgment is made of the assistance afforded in making this survey by the owners and operators of the various sewage treatment plants which were used for experimental purposes.

The assistance and cooperation of A. J. Lanning, Trenton, N. J., who designed the contact aeration sewage treatment plants now operating in New Jersey, is sincerely appreciated.

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SANITARY ENGINEER CERTIFICATION DEADLINE

October 1, 1957 is the deadline date for the receipt of applications to be considered for certification without examination by the American Sanitary Engineering Intersociety Board. Certification will be given in one of five specialties of Sanitary Engineering—Public Health, Air Pollution Control, Industrial Hygiene, Radiation Hygiene and Hazard Control, and Water Supply and Waste Disposal.

Applicants must meet three basic requirements:

1. Be currently registered as a professional engineer in one of the states of the United States.

2. Be a graduate of an accredited college of engineering or have proved experience and practice.

3. Be engaged in some aspect of sanitary engineering with at least eight years of satisfactory experience.

In order to be considered for certification without examination, the applicant must have not less than 15 years of satisfactory experience prior to October 1. Applicants with less than 15 years of experience, and all who apply after October 1, 1957, must take the two-part examination—written and oral. An application fee of $10.00 must accompany each application; the examination fee is $25.00 and must be paid regardless of whether or not the examination is waived.

Application forms and other information may be obtained from the Board Secretary, Francis B. Elder, American Sanitary Engineering Intersociety Board, Inc., 33 West 39th St., New York 18, N. Y.

PRINCIPLES AND PROBLEMS IN DEVELOPMENT OF A DISSOLVED OXYGEN ANALYZER*

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This report describes a gasometric method for obtaining a continuous record of the dissolved oxygen content of water; the design, operation, and performance of an instrument based on this method; and the problems encountered in the development of a prototype instrument. The method and instrument were developed at the Robert A. Taft Sanitary Engineering Center, Department of Health, Education, and Welfare, USPHS, Cincinnati, Ohio, for use in pollution abatement, measurement, and control programs where such equipment is needed in surveys to map rapidly the oxygen profile of a stream, or in permanent gauging stations at critical points on important streams. For potential future application, the D.O. analyzer offers a basis for networks of permanent gauging stations from which results could be telemetered to central observation stations.

The general design and performance objectives for such a dissolved oxygen analyzer include corrosion resistance and sturdiness for continuous operation in a variety of ambient conditions for extended periods of time with a minimum of maintenance. In addition, specified accuracy must be maintained in polluted water with variations in water temperature, suspended solids, dissolved solids, industrial wastes, detergents, and other similar variables. Mobility, adaptability for use on a moving boat, and rapid response to dissolved oxygen changes are required features for a rapid survey instrument. The specific goal established for the SEC † dissolved oxygen analyzer was an accuracy of ± 5 per cent of saturation for dissolved oxygen in water over a range of 0 to 150 per cent of saturation and a water temperature range of 0 to 35° C.

Principles and Design

Henry's Law of solubility for inert gases in water and the theory of aeration processes (1) are the principles involved in the method of measurement and the operation of the instrument. Their application here is best illustrated by the following analogy.

Consider first a small beaker of water deficient in dissolved oxygen, in contact with the air in a large room. Because of its D.O. deficit, the water absorbs oxygen from the air with the absorption rate decreasing with time until there is no further oxygen absorption. This reoxygenation process conforms closely to the established laws of aeration, and the final concentration of oxygen in the water is in accord with Henry's Law. The net result of the oxygen transfer process is an increase in the D.O. content of the water from its initial arbitrary deficit to a definite saturation concentration, but the oxygen content of the large volume of air remains essentially unchanged.

On the other extreme, with air in a small container exposed to a relatively large pool of oxygen-deficient water, the same principles and processes are involved but the end result is differ-

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† SEC — Sanitary Engineering Center, USPHS, Cincinnati, Ohio.

ent. Because of the very large mass of water, the concentration of dissolved oxygen is virtually unchanged by absorption of oxygen from the small quantity of air, whereas the fraction of oxygen in the container decreases gradually to a final equilibrium value. This final value for the oxygen content of the gas is a unique and reproducible function of the D.O. content of the water if expressed in terms of per cent saturation, and it is virtually independent of salt content, water temperature, and other variables.

This latter analogy, in essence, describes the manner in which the SEC dissolved oxygen analyzer operates. The large pool of water in this case corresponds to a steady stream of water passing through two chambers of the analyzer containing a small quantity of gas. As in the pool, the D.O. content of the effluent water from the analyzer chambers is essentially the same as that of the influent water, whereas the oxygen content of the gas in the chambers varies over a period of time in the same manner as the gas in the small container over the large pool.

The two chambers form an aspirator unit that is the heart of the D.O. analyzer, for all the other components of the instrument are concerned with either controlling or interpreting the aspirator-unit operation. The complete assembly and the functional relationship of the components are illustrated in the schematic block diagram of the instrument given in Figure 1. The pump supplies sample water under positive pressure to the top chamber of the aspirator unit. The water overflows the central tube in the top chamber, aspirating a small quantity of gas from the top chamber to the bottom chamber where the gas-water mixture separates at a controlled water level. The water then drains from the aspirator tube through the gas volume controller, while the gas from the bottom chamber is forced through the gas analyzer and back to the top chamber of the unit.

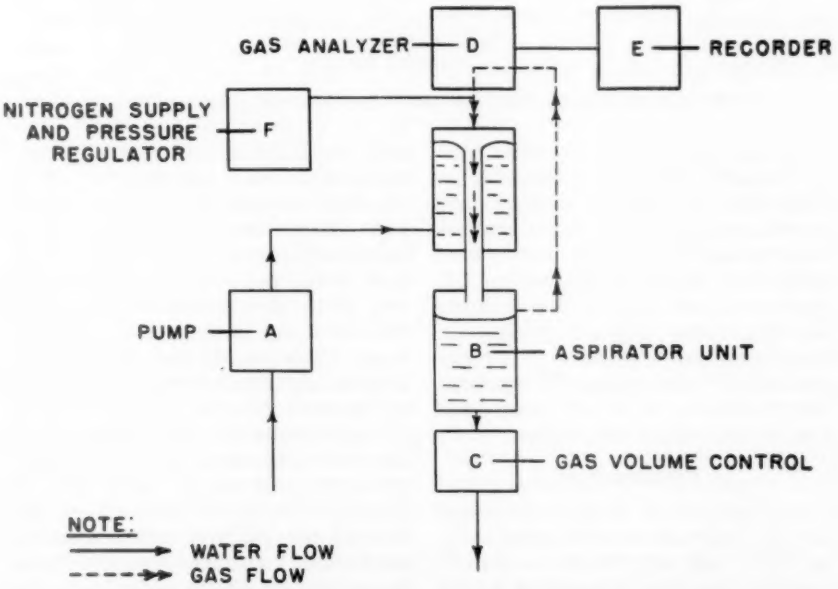

FIGURE 1.—Schematic diagram of the SEC dissolved oxygen analyzer.

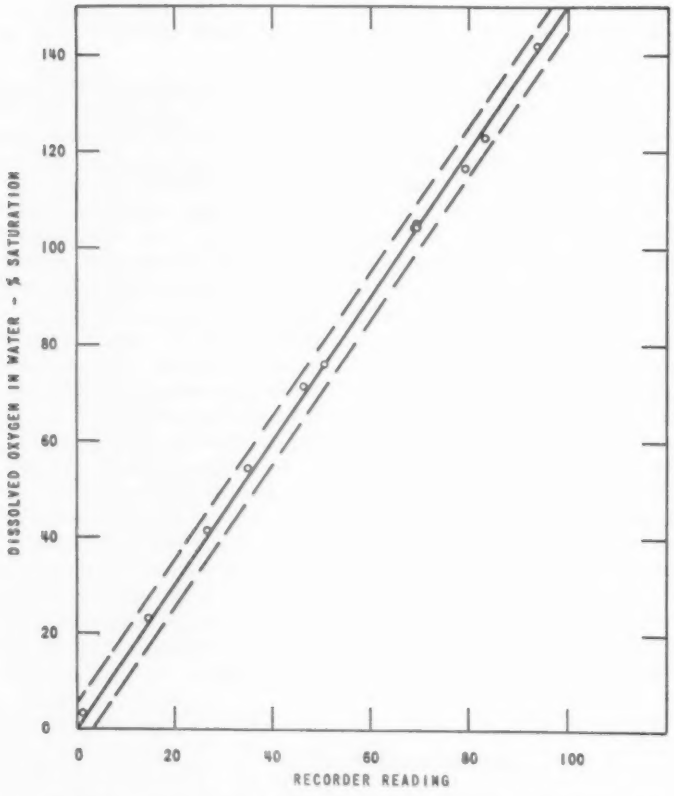

FIGURE 2.—Equilibrium response of the dissolved oxygen analyzer.

In this manner the process is readily controlled, the final equilibrium gas composition is rapidly attained, and the composition of the gas is continuously measured, recorded, and related to the D.O. content of the water. The pressure of the gas in the aspirator unit is maintained at a constant value above atmospheric pressure by a nitrogen supply and pressure regulator. This feature extends the range and adaptability of the instrument.

Performance

As described in a previous report (2), the composition of the gas in the aspirator unit approaches a definite reproducible value dependent almost entirely on the D.O. content of water and virtually independent of water temperature and salt content. With dissolved oxygen in water at 0.0, 50, and 100 per cent saturation, the respective final equilibrium oxygen content of the gas is always found to be 0.0, 10.45, and 20.90 per cent, provided the gas is at atmospheric pressure. This simple and reproducible relationship is essentially Henry's Law. At higher values for the D.O. content of water, however, small variations in barometric pressure and in the other dissolved gases in the water may indirectly influence the final oxygen content of the gas and create apparent anomalies. These interfering variables are completely eliminated by increasing the gas pressure in the aspirator unit.

TABLE I.—Equilibrium Response of Dissolved Oxygen Analyzer

Experiment (No.)	Average D.O. (p.p.m.)	Water Temp. (° C.)	Saturation, Winkler Method (%)	Recorder Reading	Saturation, D.O. Analyzer (%)	Saturation Error (%)
1	12.88	6.8	105.3	69.5	104.2	1.1
2	0.27	22.5	3.1	1.3	2.0	1.1
3	12.91	6.4	104.4	69.5	104.2	0.2
4	3.90	18.9	41.6	27.0	40.5	1.1
5	12.97	6.2	104.4	69.0	103.5	0.9
6	7.09	16.1	71.4	46.5	69.8	1.6
7	2.31	15.7	23.1	14.8	22.2	0.9
8	5.21	17.7	54.3	35.0	52.5	1.8
9	7.78	14.7	76.1	50.8	76.2	−0.1
10	14.31	15.3	141.8	94.0	141.0	0.8
11	12.39	15.4	123.0	83.5	125.2	−2.2
12	12.21	13.4	116.6	79.5	119.2	−2.6

The D.O. measurement range without interferences is greatly extended.

Figure 2 graphically illustrates the theoretical relationship between the D.O. content of water and the equilibrium oxygen content of the gas. Some recent experimental results obtained with a prototype D.O. analyzer operating with the gas at 1.20 atmospheres are also presented.

In Figure 2, the D.O. content of the water as measured by the Winkler method and converted to per cent saturation is plotted against the final recorder reading, which in turn is directly proportional to the oxygen content of the gas as measured by the gas analyzer. The solid diagonal line extending from the origin is the theoretical absolute calibration of the instrument for dissolved oxygen in water at 25° C. as derived by an independent gasometric method. Deviation of ± 5 per cent of saturation from the theoretical calibration is shown by the two broken lines parallel to the solid line. The 12 experimental points in the D.O. range of 0 to 140 per cent of saturation represent analyzer readings taken with water temperature ranging from 6.2 to 22.5° C. All 12 points agree with the independent theoretical calibration with an accuracy well within the ± 5 per cent range. Table I presents the numerical results obtained in these 12 experiments.

Theoretically, calibration for the instrument actually is temperature-dependent because of the varying vapor pressure of water, but any error in ignoring this factor is small compared to other experimental errors in gas analysis, gas volume control, response, etc., especially if a reference temperature is chosen in the middle of the temperature range considered.

Figure 3 presents the theoretical temperature calibration error as percentage deviation for reference temperatures of 15° and 25° C. over the ranges of 0° to 25° and 30° C., respectively. In no case is the error greater than ± 2.6 per cent of the reference value.

This reproducible instrument performance is practical only if the gas composition reaches its equilibrium value in a relatively short time. It is known from theoretical and experimental studies (2) that the oxygen content of the gas changes from its initial to its equilibrium value at an exponentially decreasing rate if the D.O. content of the water suddenly changes from one constant value to another. This transient condition of gas adjustment is conveniently characterized in laboratory studies by measuring the time required, $t_{0.9}$, for the gas composition to undergo 90 per cent of the change from its initial value to its final value.

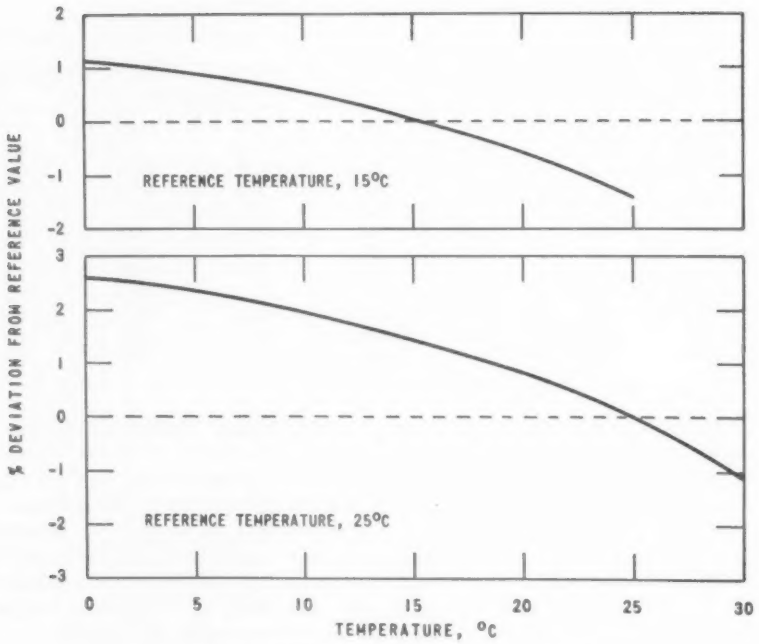

FIGURE 3.—Theoretical temperature calibration errors.

In Figure 4 a typical response curve is presented for a sudden D.O. content change. A small $t_{0.9}$ signifies that the instrument will respond rapidly to D.O. changes in water. The response rate is directly proportional to the volume of gas in the instrument and inversely proportional to the effective reaeration constant. The reaeration constant in turn depends, in this case, on the number, size, and distribution of gas bubbles, the flow of water, pollutants in the water, temperature, and a number of other factors. Most of these variables enter into the design and operation of the aspirator unit. They influence the rate of response, but they have no effect on the final equilibrium gas composition.

In early laboratory studies with the dissolved oxygen analyzer, an aspirator unit with a 40-cc. gas volume was used in which $t_{0.9}$ with tap water was about 5 min. In more recent experiments using tap water with a prototype dissolved oxygen analyzer, a $t_{0.9}$ of 35 min. was observed. The gas volume in the aspirator unit in this case was about 150 cc. Response time of the prototype increased to 43 min. with a water sample containing 2.4 p.p.m. of active Santomerse No. 3 surfactant. Finally, an additional 75 cc. of gas in the aspirator unit increased $t_{0.9}$ to 55 min.

The response-rate constant is most significant in establishing instrumental use limitations. In actual practice, the D.O. content of water usually varies slowly with time and a sudden "step" change is seldom encountered. Under these conditions, the value indicated by the D.O. analyzer will lag or differ only slightly from the true equilibrium value, depending on the rate at which the D.O. content of the water varies. For practical use it is necessary only that the lag not exceed an acceptable experimental error for the given application. It can be shown that the

application is completely defined, in terms of maximum rate of change of dissolved oxygen in water for which the instrument can be used, by specifying the acceptable error and the response-rate constant of the instrument, $t_{0.9}$.

Table II shows the relationship between $t_{0.9}$ and the maximum rate of change of dissolved oxygen in water, M, for which the instrument can be used with the error or lag in gas composition always less than ± 5 per cent of saturation. The scope of application is evident. At a permanent gauging station the rate of change in dissolved oxygen would be small and an instrument with a 35-min. response time would measure dissolved oxygen with acceptable accuracy. On the other hand, a rapid survey instrument suitable for use in a moving boat must have a small $t_{0.9}$, such as 5 min., to insure the desired accuracy.

TABLE II.—Instrumental Use Limitation *

$t_{0.9}$ (min.)	M, Per Cent Saturation/Hr.
5	138.0
20	34.5
35	19.8
50	13.8

* Acceptable error $\pm$ 5 per cent of saturation.

Design Problems and Evolution

All the experimental results presented thus far were obtained with the prototype D.O. analyzer shown in Figure 5, where all the components are shown except the water pump and the external supply of nitrogen gas. The gas analyzer used in this instrument is the Hays Corporation Magnotherm Oxygen Indicator and Recorder. It was found to be exceptionally stable and serviceable.

One major design problem requires solution before further progress can be made with this instrument. In operation, a small quantity of gas within the aspirator unit is maintained in intimate contact with a steady stream of water. The volume of the gas, under several pounds pressure, is critical and must be accurately controlled without

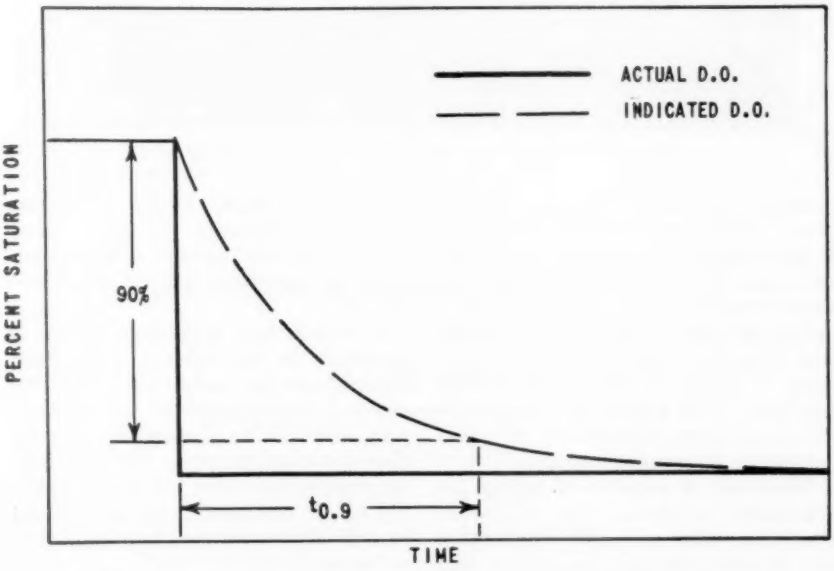

FIGURE 4.—Typical response curve of the dissolved oxygen analyzer.

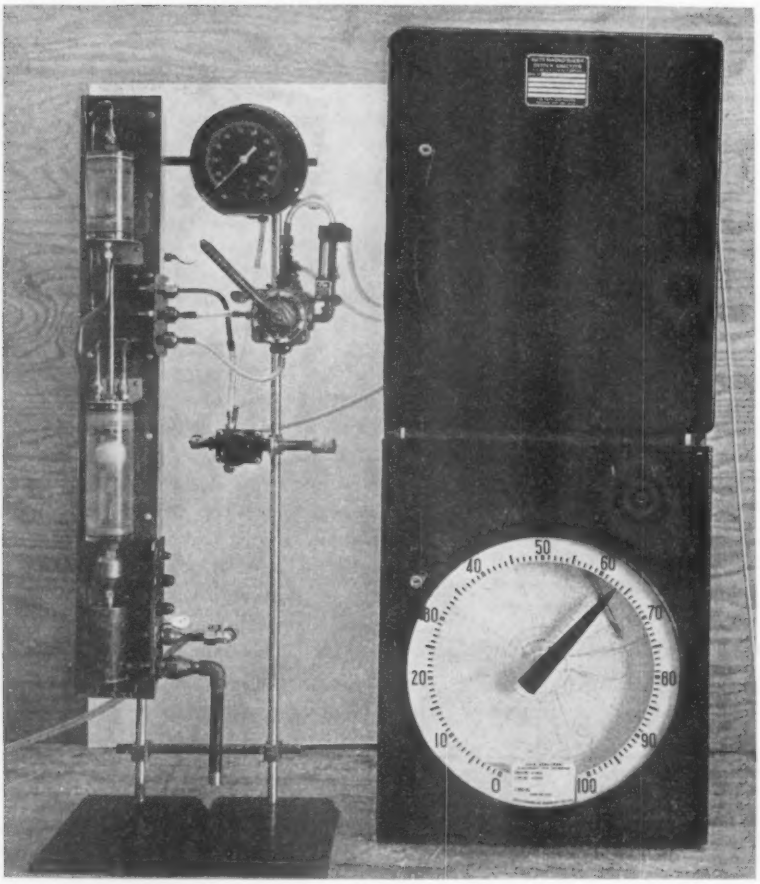

FIGURE 5.—Prototype SEC dissolved oxygen analyzer.

creating any large pressure fluctuations. This is accomplished indirectly in the prototype instrument by a sensitive liquid-level control consisting of a float-operated sleeve valve. Unfortunately, the valve fails in water containing suspended matter, and thus presents a danger of damage to the gas analyzer. This control is being modified to perform satisfactorily in water containing suspended matter.

There are a number of minor development problems. In continuous operation with a minimum of attention and maintenance, the gas volume controller and possibly other components in the instrument might fail unexpectedly. Fail-safe features must therefore be incorporated in the instrument as insurance against expensive damage.

A venting-type pressure regulator is employed in the present instrument. To minimize gas consumption from the external nitrogen supply, the present regulator will be replaced by a sensitive non-venting type. The demand for make-up gas from the external supply by the aspirator unit has not yet been firmly established, but is believed to be small.

Finally, the 35-min. response time

for the present instrument with tap water might be increased to an unsatisfactory period with polluted water or in the presence of detergents. This performance characteristic can be improved somewhat by decreasing the size of the aspirator unit to minimize gas volume, but there is a practical limit to this reduction because of liquid level control problems and increased pressure fluctuations. The minimum size has not yet been established.

The present aspirator unit design appears to be adequate for many potential applications. Many different designs and devices, however, may possibly function as well as or better than the present unit. Work has begun on a new aspirator unit design in which the size and gas volume would be considerably reduced. The gas volume control under consideration is expected to be useable on a moving boat.

Any nondestructive gas analyzer specific for oxygen is suitable for the D.O. analyzer. The Hays Magnotherm Analyzer was found to perform satisfactorily. To reduce size, weight, or cost, other gas analyzers might be used as suited to requirements. Choice of gas analyzer is somewhat academic at present, because further development work and field testing on other components of the D.O. analyzer are required before this selection can be properly considered.

Ultimate and Limited Objectives

After satisfactory redesign and development of the present gas-volume controller, the D.O. analyzer will be field-tested under a variety of use conditions to establish field performance, necessary field maintenance schedules, and any further necessary redesign of critical components.

The instrument with indicated changes should be suitable for use in permanent gauging stations. It is expected that subsequent engineering design and development will reduce the instrument to a more portable survey instrument, serviceable on a boat or other vehicle.

Ultimately, additional accessory instruments can be integrated with the D.O. analyzer to provide simultaneous readings of temperature, and perhaps of electrical conductivity. The continuous record of dissolved oxygen in per cent saturation could then be converted to parts per million, even for brackish or tidal waters.

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30TH ANNUAL MEETING

of the

FEDERATION OF
SEWAGE AND INDUSTRIAL WASTES
ASSOCIATIONS

HOTEL STATLER

BOSTON, MASSACHUSETTS

October 7-10, 1957

SEWAGE TREATMENT PLANTS FOR THE NEW YORK STATE THRUWAY *

By Irwin P. Sander

Senior Sanitary Engineer, New York State Thruway Authority

As has happened so often in this country, an American institution which had vanished from the scene because of progress, has once again reappeared. This is the toll-road inn that flourished in the late 18th and early 19th centuries. Unlike the inns of the earlier years, the modern inns do not provide lodging for the traveler but they do have facilities for all of his other needs. These are the "service areas" which are becoming so familiar to those who travel the turnpikes and thruways which are beginning to criss-cross America.

New York Thruway Service Areas

On the New York State Thruway, 25 of these service areas are planned for the section between New York and Buffalo. Twenty-one of these are already in operation and it is anticipated that the remaining four will be completed in 1957. In addition, there will be two service areas on the Erie section of the Thruway and one on the Berkshire section, bringing the total to 28. Construction on these is scheduled to begin in the latter part of 1957 or early in 1958.

Types of Sewage Treatment

Of the 28 planned service areas, only three are located so as to be tributary to municipal sewage systems and it has therefore been necessary to provide some sewage treatment facilities at the remaining 25. Inasmuch as the locations of these service areas were determined by considerations other than those which would make possible the most economical sewage treatment facilities, it has often been found necessary to provide the highest degree of treatment since the available receiving streams were inadequate to accept even a highly purified effluent. Table I shows the types of treatment which are being planned for the 28 service areas on the Thruway.

Primary Facilities

The degree of treatment required in each area was determined by engineers of the New York State Department of Health so as not to contravene the established or proposed standards for the receiving stream under the New York State Water Pollution Control Act. As indicated in Table I, primary sewage treatment plants were permitted at only five locations. These are situated near large streams; four discharging directly into the Mohawk River and the fifth into the Genesee River.

Secondary and Tertiary Facilities

The secondary and tertiary facilities, required at 20 sites, are all high-

TABLE I.—Sewage Treatment Planned for the 28 Service Areas

Type of Treatment	Service Areas (No.)
Municipal	3
Primary	5
Secondary	7
Tertiary	13*

* Includes two plants on Erie section and one on Berkshire section in anticipation of probable final decision.

* Presented at 1957 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 17–18, 1957.

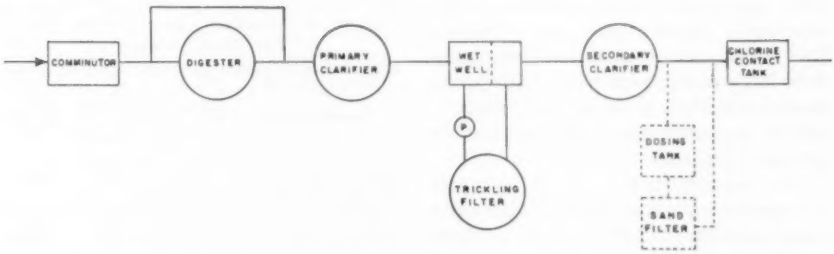

FIGURE 1.—Typical flow diagram for sewage treatment plants, New York State Thruway.

rate trickling filter plants, using the direct recirculation process. Figure 1 is a flow diagram of the sewage flow through a typical plant of this type. Sewage from the service area reaches the plant site by gravity at all locations except two where lift stations are used.

The raw sewage enters the plant at the comminutor chamber. This chamber is equipped with a comminuting device and also with a manually-cleaned bar screen that is used during power failures or when repairs are being made on the motor-operated equipment. From the comminuting chamber, the sewage may be directed to the digester for predigestion or, alternatively, to the primary clarifier if the plant is to be operated conventionally.

At the present time the plants are operated conventionally because flows are so much below the design loads that the detention times for the primary clarifier and digester would be excessive and would cause a very septic sewage to be discharged from the primary clarifier. At a few of the plants it was possible to have a bypass line installed around the primary clarifier. It is hoped that, by use of this line, the effects of placing supernatant liquor directly on a trickling filter can be evaluated.

Sewage entering the primary clarifier may be chlorinated for odor control should the need arise. Both circular and rectangular clarifiers have been installed. All provide for mechanical scum and sludge removal. The effluent from the primary clarifier flows by gravity to a wet well where it is mixed with recirculated sewage from the trickling filter and then lifted to the trickling filter. The trickling filter effluent flows back to a second section of the wet well and a quantity equal to the difference between the plant influent and the capacity of the pumps is returned to mix with the primary clarifier effluent so that a constant volume is always flowing over the trickling filters. An amount equal to the plant influent therefore reaches the secondary clarifier and, at times when the flow entering the plant is just a trickle, the entire flow passing over the trickling filter is recirculated.

At some locations, recirculation ratios of better than 50 to 1 are experienced during the winter months, due to low influent flow. This is contrasted to a design recirculation ratio of 2 to 1. Sewage from the secondary plant flows to the chlorine contact tank and is then discharged to the receiving stream. At tertiary plants during the summer months, the secondary clarifier effluent flows to a dosing tank that discharges on to an open sand filter. The sand filter effluent flows to the chlorine contact tank before final discharge.

Two methods of chlorination are in use at the present time. The first five plants that were built were equipped

with hypochlorinators while the remaining 17 plants have gas machines. Due to water conditions the hypochlorinators have not worked satisfactorily and it is expected that they will be replaced with gas machines in the near future.

The piping in the pump house is arranged to provide flexible operation and maximum utilization of the pumps. Valving is provided so that either primary or secondary sludge can be pumped. Two pumps are available so that if one pump fails, the other can be used.

Digested sludge has to be carried from the site by tank truck. To date, only one station has built up enough sludge so that sludge had to be withdrawn. At the Junius Ponds Service Area, 17,500 gal. of sludge were withdrawn from the digester which has a capacity of 75,000 gal. This sludge, which had a solids content of 10.4 per cent and a volatile solids content of 53 per cent, was dumped on farm land about one-half mile from the service area. No odors were noticeable by any of the surrounding inhabitants and no nuisance conditions were observed.

An interesting feature of the trickling filter is the roof which has been placed over it. As shown in Figure 2, air is sucked into the filter through the four pipes on the outside and positive ventilation is provided by the fan on the roof. The roofs were provided to eliminate, as much as possible, the chance that any psychoda flies which might grow in the filter, might migrate to the service area proper and become a nuisance to restaurant patrons.

TABLE II.—Analysis of Sewage (11-Hr. Composite) at Chittenango Service Area, New York State Thruway

Sampling Point	B.O.D. (p.p.m.)	Suspended Solids (p.p.m.)	Grease (p.p.m.)
Plant influent	384	210	229
Primary clarifier effluent	408	200	103
Final effluent	48	66	18

Analytical Data

To date little analytical data have been collected at any of the sewage treatment plants. One plant has been sampled as part of the survey of the Oswego River Basin by the New York Water Pollution Control Board. This plant, located at the Chittenango Service Area, affords secondary treat-

FIGURE 2.—Exterior view of trickling filter, New York State Thruway. Note cover.

ment. Results of the analysis are shown in Table II. It can be seen that a reduction of 87.5 per cent occurred in the B.O.D. The suspended solids were reduced only 68.5 per cent. As the author was not present at the time of the sampling, no attempt will be made to interpret the cause of the low suspended solids removal. A sampling program is now being instituted at each sewage plant and it is hoped that some valuable information can be obtained. However, since the man who will be attending the sewage treatment plant will also be the general mechanic for the whole service area, the tests that are to be performed will necessarily be kept to a minimum. Tests that are to be done will include methylene blue, suspended solids, chlorine residual and possibly pH.

QUARTER CENTURY OPERATORS' CLUB MEMBERSHIPS INVITED

Membership applications for the Quarter Century Operators' Club are invited from all sewage and industrial waste treatment plant operators who operated a treatment works 25 or more years ago. To be eligible for membership the candidate must have been in full-time resident charge of the operation of a sewage treatment plant 25 years prior to the date of his admission to the Club. It is not a requirement that the candidate still be in responsible charge of a treatment plant or in the field of works operation. However, it is expected that he have a continuing interest in the field of sewage and industrial waste treatment.

Applications may be obtained from Club Chairman Henry Van Der Vliet, P. O. Box 281, Rutherford, N. J. All who are eligible at this time or will be eligible by October 6, 1957, are urged to submit their applications promptly, in order that they may be officially considered by the Federation Board of Control at the Board Meeting on October 6.

UTILIZATION OF SEWAGE FOR CROP IRRIGATION IN ISRAEL *

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Editor's Note—This paper is based on first-hand knowledge of the sewage use practices in Israel as observed by the author while on a Foreign Aid Overseas (FAO) mission in 1956.

It is important to draw a clear distinction between the disposal of sewage on land and the utilization of sewage for crop irrigation. Failures and difficulties with the disposal of sewage by crop irrigation need not arise when utilization is the main objective. The natural tendency with land disposal of sewage is to apply as much sewage as possible in a limited area at rates higher than can percolate through the soil. Waterlogging of the soil and odors are the common result of such practice. The anaerobic condition which may result is known as "soil sickness." On the other hand, when the application of sewage to the land is geared to the needs of the soil and the crop, odor and waterlogging difficulties do not arise. There are a number of examples all over the world of successful utilization of sewage for crop irrigation.

It is the thesis of this paper, that under proper climatic and soil conditions and with proper control of irrigation for crop production, the use of sewage effluents need not create nuisance conditions or health hazards. Furthermore, for certain areas of the world crop irrigation represents an economic necessity for the development of agriculture, while at the same time it solves satisfactorily the sewage disposal problem. This paper will delineate the conditions under which crop irrigation with sewage becomes an attractive proposition.

The Rainfall Factor

Successful utilization of sewage for crop irrigation depends primarily on the amount and distribution of total annual rainfall. During the growing season, the rainfall must be sufficiently low to make use of substantial volumes of sewage for supplemental irrigation. In humid regions with an annual rainfall of 40 to 45 in., this utilization is limited to occasional supplemental irrigations during the growing period when rainfall is deficient for maximum crop growth. This is also true in regions where the annual rainfall is less than 40 to 45 in., but where there is adequate rainfall during the growing season.

If there is adequate rainfall during the season when crops are not grown, sewage may be disposed of with or without treatment into water courses, depending on the stream flow and other local conditions and requirements. Or sewage may continue to be applied to the soil even during the non-growing season, provided the rainfall during this period is not in excess of the absorptive capacity of the soil, and sufficient land is available to absorb the sewage and thereby avoid excessive dosages and waterlogging. Under certain conditions, it may even be feasible to impound the sewage with or without surface runoff during the rainy non-growing season for irriga-

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University.

tion use during the growing season. If the soil is sufficiently porous, it may be advisable to spread the sewage on the ground for recharge of underground water supplies.

Imhoff and Fair (1) state that sewage irrigation is not practicable in areas with more than 25 in. of rainfall. In Israel rainfall varies from a maximum of 40 in. in a limited area to almost no precipitation in the southern part of the Negev.* In the greater part of the coastal plain area, the rainfall averages about 20 in. and in the northern Negev about 6 to 12 in.

The rainfall occurs only during a period from November to April. Most of the streams become dry wadies during the balance of the year. Consequently, irrigation is required 220 days of each year. The need for irrigation during the season of rainfall depends on the amount of annual rainfall and the climate. For instance, with sufficiently high temperature in the winter and only 6 to 12 in. of annual rainfall, agriculture is feasible in the Negev the year-round with supplemental irrigation in the winter.

Need for Sewage Utilization

In Israel it is not the lack of land that controls further expansion of agriculture, but rather the limitation of water for irrigation. Even if all potential water supplies are developed in the next 10 years, there will still be insufficient water to irrigate all the available land. It is therefore proposed that the water supply be augumented by the utilization of sewage and industrial wastes for irrigation purposes. Only 50 per cent of the sewage and industrial wastes is estimated as available for utilization. The total volume of water required for irrigation will be 400 billion gallons per year in 10 years. Utilization of sewage will be counted on to furnish 10 per cent of this volume. This would be sufficient to bring an additional 50,000 acres under cultivation.

The problems involved in the realization of this goal are: (a) construction of collection systems for the wastes, (b) transmission of the sewage to the agricultural areas, (c) provision for adequate treatment of the wastes prior to irrigation, and (d) development of suitable farming areas and practices for the utilization of the wastes.

The best information available indicates that in 1955 only 38 per cent of the population living in urban centers was served by sewers, the rest being served by septic tanks and percolation pits. In large towns like Tel Aviv, Haifa, and Jerusalem, the results of this situation are obvious. Construction of sewers is a paramount necessity from the standpoint of public health, regardless of whether or not the sewage is to be utilized for agriculture. Once the sewage is collected, its utilization for irrigation provides the best answer for the conditions which prevail in most parts of Israel.

The distance sewage can be transported for utilization depends on the location of available agricultural areas from the sources of sewage and on the volume of sewage available. It is preferable to treat sewage near the source of origin and transport the treated effluent to the nearest area where it can be utilized. In certain cases, when the volume of sewage is large, it may be transported considerable distances, as for instance, in the case of the plan to utilize Tel Aviv sewage in the Negev some 60 miles away. Sewage from villages and agricultural settlements is best used locally.

Present Status

Knowledge of the extent of the present use of sewage irrigation in Israel and of the experience from present practices are a basic need for the preparation of future plans. In large towns this can be determined readily.

* The Negev, located in the southern part of Israel, comprises the largest part of Israel territory and is considered a desert. It is presently being developed for agriculture.

Sewage from Tel Aviv and Haifa is being considered for utilization only in terms of the future. Part of Jerusalem sewage is presently being utilized on two farms in the vicinity.

The total volume used in Jerusalem and other municipalities and townships is estimated to be about 400 million gallons per year. An additional 265 million gallons per year is utilized by agricultural settlements on their own farms. The total volume of sewage presently utilized represents only 4.5 per cent of that now available. The percentage of available sewage actually utilized is higher in agricultural settlements than for the country as a whole. The national plan for irrigation development in the next 10 years provides for the utilization of 40 billion gallons of sewage per year. The gap between the present total volume utilized and future planned volume indicates the size of the task to be accomplished.

Irrigation Application Rates

Under conditions prevailing in Israel, the application rate of water for crop irrigation is 20 to 30 in. per year. Imhoff and Fair (1) state that in well-watered regions the annual irrigation depth is about 10 in. (one-half to one-third of the annual precipitation). If the land is assumed to be irrigated once in 10 to 15 days, during 220 days there would be 15 to 20 applications with each application amounting to ½ in.

Irrespective of the method of irrigation (furrow, spray, or surface irrigation), the author observed no odor nuisances created on land irrigated at such rates in Israel. It is the furrow type of irrigation that is most likely to create odor problems. Where the sewage is confined to a limited area, irrespective of type of soil, a few hours after irrigation ceased there was no standing water in the furrows. The next day, the furrows were moist with some deposit of sewage solids in the bottom near the inlet end of the furrow. This sludge cracked on drying and apparently did not affect the percolation of the subsequent applications during the growing season. Upon plowing, the sludge was distributed, assimilated, and decomposed in the soil. The length of time that the furrows remain moist depends on the distance between rows and the height of the crop.

Odors could only be detected if sewage applied to the field had developed septicity prior to its arrival at the field, as a result of improper operation of the sewage treatment plant. Odor problems associated with septic sewage were more acute with spray than with furrow irrigation. There were no evidences of fly breeding on land irrigated with sewage; the fly population here did not seem any greater than in any other area within the vicinity not irrigated with sewage.

Thus, when the rate of sewage application fits the needs of the crops, odor or fly problems apparently are not created. The degree of sewage treatment furthermore need not be high to prevent nuisance conditions from arising when sewage is applied in accordance with crop needs. The assimilating capacity of soil for the organic matter in the sewage is not exceeded by such rates of application, and the organic matter decomposes readily, contributing to the soil humus. The nutrient elements bound in the organic matter are released slowly and made available for plant utilization, in addition to the soluble nitrogen and phosphorus contained in the sewage. Pretreatment of sewage should, therefore, not have the objective of B.O.D. removal since the B.O.D. can be conveniently removed in the soil in conjunction with crop irrigation.

Primary Versus Secondary Treatment

The question might be raised as to whether or not a more complete treat-

ment of irrigation sewage may be necessary as insurance against health hazards. There are two alternatives that might be followed:

1. The sewage could be subjected to secondary treatment and thorough disinfection and the effluent used for unrestricted crop irrigation,
2. The sewage could be given the minimum treatment possible and the effluent utilized without disinfection for irrigation of crops not eaten raw by human beings.

Before discussing the pros and cons of these alternatives it is well to consider whether there is a sufficient number of crops that can be raised by irrigation with partially treated sewage to make the second alternate attractive and feasible.

The following list of crops that may be raised by irrigation with primary treated sewage alone was drawn up by the Israeli Ministry of Health: varieties of beets raised for the manufacture of sugar and for stock feed, cotton, pasture and hay, vegetables that are eaten only after cooking, such as eggplants, white and sweet potatoes, okra, sweet corn, olives and dry onions, fruit trees such as citrus, banana, nut, date and avocado, nursery plants, ornamental plants and flowers, sunflowers and carobs when furrow-irrigated, apples, pears, and plums when irrigation is stopped at least one month before harvesting, and plants grown for seed. To this list could be added: broccoli, cauliflower when furrow irrigated and tomatoes used for canning when furrow irrigated. Obviously a number of plants can be raised safely with partially treated sewage.

The decision to treat sewage by either primary or secondary methods depends, among other things, on the size of the community. It is unthinkable, even with Israel's need of irrigation water, that sewage from villages and agricultural settlements can be treated by activated sludge or trickling filter processes and adequately disinfected for unrestricted irrigation. The cost of the effluent would far exceed the cost of clean water and the control of the quality of the effluent due to inadequate operation would be difficult. Although these difficulties would not be so acute with larger sewage flows, such as from Tel Aviv or Haifa, the necessity of going to secondary treatment even in these cases is questionable. It is possible for instance to treat the sewage from Tel Aviv by plain sedimentation, transport the effluent to the Negev some 60 miles south, and utilize it there for raising a number of crops (primarily cotton, citrus fruits, and pasture and hay) instead of the proposed treatment by the activated sludge process and chlorination, using the effluent for unrestricted crop irrigation.

The author does not consider that the health hazards involved in the latter case are less than those involved in the plan using partially treated sewage for restricted crop irrigation. On the contrary, the opposite may be true because of such factors as inevitable process failures, equipment breakdowns, and poor operation. Unrestricted crop irrigation with so-called completely treated sewage may involve greater health hazards. Aesthetic considerations also operate against unrestricted irrigation of edible crops even with completely treated and safe effluents.

The problems of hydrogen sulfide production and sewer corrosion associated with the transportation of the settled effluent some 60 miles are not as great as might be supposed. In the absence of sludge deposits in the sewers, hydrogen sulfide production does not take place rapidly enough to cause a serious corrosion problem. From the standpoint of the fertilizer value of the sewage, the advantage is in favor of primary treated effluent.

Type of Primary Treatment

For crop irrigation, the following methods of primary sewage treatment are considered:

1. Screening or comminution.
2. Plain sedimentation tanks.
3. Imhoff tanks.
4. Septic tanks.
5. Earth basin tanks.

The particular type of primary treatment selected will depend in general on (a) size of the plant, (b) cost of construction, and (c) ease of operation.

Some types of primary treatment are not as well suited for large treatment plants as they are for smaller installations. The septic tank or the earth basin type of treatment, for instance, would not be advisable for a plant of the size necessary to serve Tel Aviv. The choice in such cases is between plain sedimentation and Imhoff tanks. For small villages and agricultural settlements, septic tanks or earth basin tanks may be preferable to plain sedimentation or Imhoff tanks. The principal considerations in the selection of treatment for small installations are ease of operation and cost. During the author's mission in Israel 35 small primary sewage treatment plants of various types were visited at agricultural settlements, housing developments, villages and towns. With only a few exceptions, the operation of these plants was badly neglected. As a result, performance of the plants was poor and the sewage was septic.

Since the simplest unit to operate is obviously the preferred choice, some consideration should be given to the simplest of all types of primary treatment—screening or comminution. Only a minimum amount of time is required for the operation and maintenance of these devices. The sludge problem, however, is transferred from the treatment tanks to the storage tanks and then to the distribution ditches. Storage tanks are generally provided with irrigation schemes for the purpose of leveling out the flow; sludge would settle in these units if the sewage were not previously settled. Removal of settleable solids is therefore important in sewage irrigation schemes. The removal of the separated sludge and scum from the primary treated sewage should be accomplished with a minimum of attention.

Plain sedimentation tanks wherein sludge and scum must be removed daily or else function as septic or Imhoff tanks are not recommended for small installations. Imhoff tanks are not preferred because the necessary attention to sludge and scum removal may be ignored. Foaming problems with Imhoff tanks were not observed or reported for Israel conditions, perhaps because fairly uniform temperature conditions prevail throughout the year, in contrast to conditions in the northern United States and Canada.

The type of earth basin tanks envisioned here is essentially a septic tank and not an oxidation pond for complete treatment of sewage. The scheme consists of earth basin sedimentation tanks followed by detention in a lagoon. There should be two sedimentation basins for alternate cleaning and use, with sludge removal once or twice a year. The septic sewage from the sedimentation tank is detained in the lagoon just long enough to remove the hydrogen sulfide odors by atmospheric and photosynthetic reaeration.

The author observed seven earth basin installations and, with one exception, the performance of the units and the quality of the effluent was quite satisfactory. The black septic effluent from the sedimentation tanks became odorless in the lagoons and even contained some green microscopic growth. The detention period and the population loading of these seven installations are given in Table I, to-

TABLE I.—Detention Time and Loading of Some Sewage Lagoons

Lagoon (No.)	Detention Time (days)	Population Loading (no./acre)	Influent (p.p.m.)	Effluent (p.p.m.)	Removal (%)	Dissolved Oxygen	
						Day (p.p.m.)	Night (p.p.m.)
1	1.75	13,200	280	57	80	3.4	0
2	21.0	2,000	350	62	80	18.9	0
3	4.4	2,500	—	—	—	—	—
4	4.6	3,700	—	—	—	—	—
5	4.6	2,700	—	—	—	—	—
6	4.0	3,600	—	—	—	—	—
7	5.0	16,000	—	—	—	—	—

gether with the B.O.D. and dissolved oxygen values available.

Despite the fact that hydraulic and population loadings are much higher than those commonly used in oxidation ponds in the United States, performance was good as judged by the suitability of the effluent for restricted crop irrigation. The constant bright sunshine during the entire summer period is a favorable factor in the photosynthetic reaeration of these lagoons. Additional work needs to be done to evolve basic design data for construction of lagoons under Israel conditions, both for partial treatment in conjunction with irrigation of the effluent and for complete treatment for discharge into watercourses.

Effect of Irrigation

Some work has been done by the Israeli Ministry of Agriculture to determine the effect of the chlorides in the irrigation sewage on the physical and chemical properties of the soil. Because water consumption in Jerusalem is 20 g.p.c.d., the concentration of chlorides is high. In municipal water it is 80 p.p.m. and in the settled sewage it is 400 p.p.m. Settled sewage and trickling filter effluent with essentially the same chloride content were applied on experimental plots and compared with irrigation with municipal water over a period of three years. The plots irrigated with sewage effluent showed an accumulation of salts, especially chlorides, which were concentrated to a large extent in the upper layers of the soil. These salts, however, were leached out of the soil during the rainy season and the soil returned to its preirrigated state in respect to salt concentration.

The amount of organic matter in the soil irrigated with sewage effluent increased gradually, thus increasing the fertiliity of the soil.

The effect of sewage irrigation on crop production should be evaluated on the basis of both the value of the water and the contribution of nutrient elements. In the major part of Israel there can obviously be no crop production without some kind of irrigation. Any comparison of crop production is necessarily on the basis of water versus sewage for irrigation.

The use of sewage adds to the soil 2.5 to 3 kg. of nitrogen, 1.0 kg. of phosphorus, and 1.3 to 1.6 kg. of potassium per capita per year. The fertilizer value of sewage has been estimated to be somewhat greater than its water value. When sewage is used for crop irrigation in the required quantities, more nitrogen is supplied than can be utilized by crop growth. The supply of phosphorus and potassium under these conditions is estimated to be approximately equal to the demand of the crop.

Crop yields were also studied in the Jerusalem experiments previously referred to. Check plots receiving water were fertilized with nitrogen, phosphorus and potassium, and stable

manure, whereas sewage-irrigated plots received no additional fertilizers or manure. On the sewage-irrigated plots crop yields were considerably higher than on the check plots. These statistically significant differences were attributed to the fact that with sewage irrigation the plants received nutrients at regular intervals throughout the growing season and not just at the beginning. The increase in soil fertility and the regular supply of sewage enabled the plants to overcome the effects of soil salinity.

Reference

1. Imhoff, K., and Fair, G. M., "Sewage Treatment." John Wiley and Sons, Inc., New York, N. Y. (1940).

MEETINGS OF INTEREST

1957

Aug. 19–23 **Massachusetts Institute of Technology.** Disposal of Industrial Wastes from the Textile Industry. Summer Session, M.I.T., Cambridge 39, Mass.

Aug. 20–22 **Northwestern University.** Liquid scintillation counting. Associate Professor Carlos G. Bell, Jr., Northwestern University, Evanston, Ill.

Aug. 26–28 **Hydraulics Division,** American Society of Civil Engineers, Kresge Auditorium, Massachusetts Institute of Technology, Cambridge, Mass.

Sep. 15–18 **American Institute of Chemical Engineers,** Lord Baltimore Hotel, Baltimore, Md., F. J. Van Antwerpen, Secretary, 25 West 45th St., New York, N. Y.

Sep. 22–25 **Public Works Congress and Equipment Show,** Philadelphia, Pa. Donald F. Herrick, Executive Director, American Public Works Association, 1313 East 60th St., Chicago 37, Ill.

Oct. 7–10 **Federation of Sewage and Industrial Wastes Associations,** Hotel Statler, Boston, Mass.

Oct. 7–8 **Bavarian Biological Institute,** Munich, Germany. Advance course in the biological and chemical problems of trickling filters and activated sludge. Dr. H. Liebman, Bayerische Biologische Versuchsanstalt, Veterinarstrasse 13, Munich 22, Germany. Applications by Sep. 30.

Oct. 14–18 **American Society of Civil Engineers,** Annual Convention, Hotel Statler, New York, N. Y. W. H. Wisely, Executive Secretary, 33 West 39th St., New York 18, N. Y.

Nov. 11–15 **American Public Health Association,** 85th Annual Meeting, Cleveland, Ohio. R. M. Atwater, M.D., Executive Secretary, 1790 Broadway, New York 19, N. Y.

IMPROVEMENTS AT SOUTHERLY SEWAGE TREATMENT PLANT, CLEVELAND, OHIO *

By Walter E. Gerdel †

Superintendent, Southerly Sewage Treatment Plant, Cleveland, Ohio

From 1950 to the present time, the City of Cleveland has spent approximately $10 million for improvements, enlargements, and modernization of the Southerly sewage treatment plant.

The cost of the entire construction program was originally estimated at $14.4 million in 1951. The work so far completed has run about 110 per cent of the original estimates, during a period when the cost index has risen steadily. The principal items still to be constructed are: (a) additional sludge filtering and incinerating facilities; (b) repairs and conversion of the Imhoff tanks to secondary digesters; (c) construction of a service building; and (d) a general clean-up contract to take care of street lighting, road repairs, and other miscellaneous items. In addition, the present vacuum filtration and sludge incineration facilities, which are nearly 20 years old, will have to undergo major replacement or rebuilding in the near future. Consideration is also being given to making certain improvements to reduce the flood hazard at the plant.

The net effect of this construction program, has been to take an overloaded plant of the Imhoff tank-trickling filter type (which also had an abbreviated activated sludge plant in parallel with the trickling filters) and convert it into a larger-capacity, modern, up-to-date, complete treatment plant of the activated sludge type. The capacity of the plant is now 68 m.g.d. raw sewage flow, plus 6 m.g.d. of elutriate at design detention times. In addition, the plant has been provided with a 9 ft.-diameter outfall sewer in parallel with the original 8 ft. 6 in.-outfall sewer. This new sewer provides the additional capacity needed for taking higher flows through the plant, as well as furnishing ample by-pass capacity in the event of abnormally high sewage and storm water flows or high Cuyahoga River elevations.

The Southerly sewage treatment plant (Figure 1), being located on the Cuyahoga River, differs somewhat from the other two Cleveland sewage treatment plants which are situated on the shores of Lake Erie. The Cuyahoga River is subject to very rapid fluctuations in river elevation and these naturally affect the operation of the sewage treatment units. Lake Erie elevations change slowly and the changes are limited in scale, so that the discharge of effluent rarely presents a problem at the lakeside plants and flooding danger at these plants is much reduced. The various Southerly plant conduit connections to the outfall sewer are provided with either tide or sluice gates for high water protection. At the point of junction of the two main interceptors, there are overflow and by-pass storm-water facilities and sluice gates. These connect to the new 9-ft. diameter outfall sewer. One of the electrically-operated sluice gates on the Southerly interceptor is automatically operated when the maximum safe water elevation is reached.

* Presented at the 1956 Annual Meeting of the Ohio Sewage and Industrial Wastes Treatment Conference; Cleveland, Ohio; June 13–15, 1956.

† Presently, Commissioner, Division of Sewage Disposal, Cleveland, Ohio.

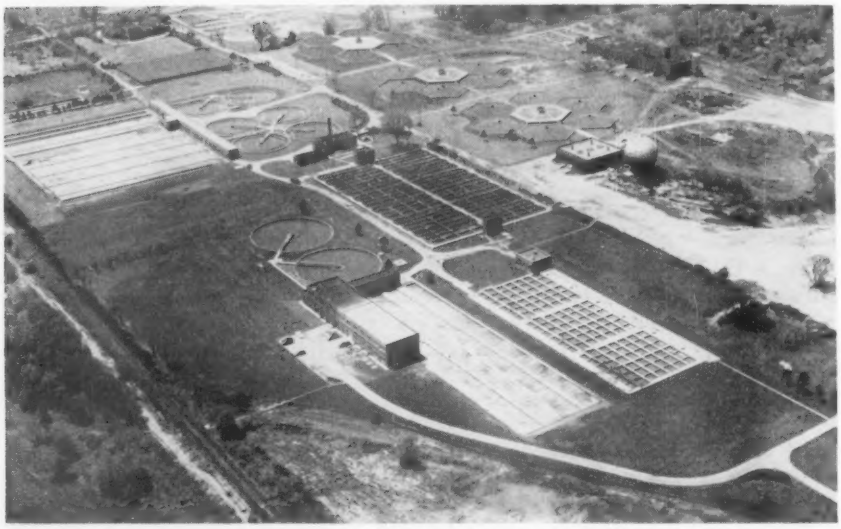

FIGURE 1.—Aerial view of the Southerly Sewage Treatment Plant, Cleveland, Ohio.

Pretreatment Facilities

The new facilities provided for pretreatment consist of two detritor units, each 40 ft. in diameter, with a combined capacity of 102 m.g.d. Organic returns wash the grit which is discharged to portable steel pans, each with a 2-cu. yd. capacity. The pans are set in industrial cars (Figure 2) on tracks to expedite transfer. A 5-ton crane is used to move the pans from the cars and position them for removal from the building. The grit is dumped in low areas and covered by ash from the incinerators. Just ahead of the detritors is a coarse set of bar gratings with 4-in. openings whose principal function is to catch material which might damage the detritors or the comminutors. Rags and other materials which tend to collect on the gratings are pushed off into the sewage flow.

Immediately downstream of the detritors are five 36-in. comminutors with ⅜-in. slots. These are equipped with stellited shear bars and combs and with stellited cutting teeth faced with tungsten carbide cutting edges. The location of the comminutors on the downstream side of the detritors has provided an installation which has been remarkably low in maintenance costs. This is in contrast with the older installations at the Easterly plant where the comminutors were placed upstream from the detritors.

As a precautionary measure to prevent overloading of the detritors during storm flows, each detritor at Southerly is pumped down every two weeks and cleaned of the rags which cling to the revolving raking mechanism. The overloads which have occurred in the detritors have been confined to one unit which, because of the sewage conduit layout, receives the largest portion of grit, rags, and other coarse material. A feature of this unit is a safety alarm system which automatically starts a ventilating fan and sounds an alarm if the atmosphere immediately above the sewage flow reaches 20 per cent of the lower explosive limit.

The original pretreatment facilities, which were buit in 1927 and consist of four sets of bar gratings and four

grit chambers, have been retained to provide parallel facilities for pretreatment of sewage in excess of that taken through the detritor-comminutor unit. The bar gratings and grit chambers are conservatively rated at 68 m.g.d. This increases the total capacity of the pretreatment units to 170 m.g.d. An interesting feature is the flushing system and the method by which screenings, removed at the bar gratings in the old screen building, can be water borne to the upstream side of the comminutors.

Primary Sedimentation

The original plant provided 12 Imhoff tanks rated at 36 m.g.d. at 2-hr. detention time. These tanks have been abandoned as sewage treatment units and six new single-pass primary settling tanks have been provided. These are designed to provide a detention period of 90 min. for an average flow of 68 m.g.d. and to treat all flows up to a maximum rate of 170 m.g.d. The tanks are equipped with sludge-removal mechanisms and surface-skimming mechanisms of the chain-driven straight-line type (three flights in each tank with a cross conveyor at the inlet end for concentration of the sludge). The tanks have a side-water depth of 15 ft. 5 in. and 312 ft. of weir length. Overflow rate at 68 m.g.d. is 36,350 gal. per foot of weir per day.

Sludge is drawn from each tank through separate sludge lines to telescopic valves and discharged to a sludge sump. Visible discharge of the sludge at the telescopic valves is provided for control purposes with ample forced ventilation eliminating possible odor nuisance. Two variable speed screw-feed pumps are available for pumping the raw sludge to the digesters. A raw sludge Venturi meter, with a purge system, meters the sludge flowing to the digesters.

Another feature of the unit is air agitation of the inlet channel to the primary settling tanks. Settled sewage flows, in excess of the flow being treated in the aeration units, are over-

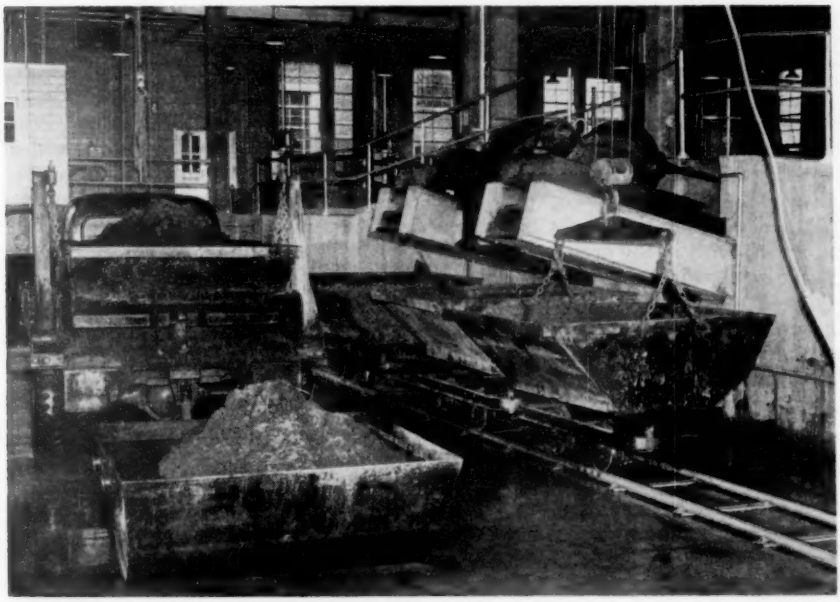

FIGURE 2.—Grit handling facilities.

flowed automatically over a weir and discharged to the outfall sewer.

Secondary Treatment

Secondary treatment facilities at the Southerly sewage treatment plant consist of two complete and independent activated sludge units. The smaller unit, having a capacity of 22 m.g.d., consists of two double-pass aeration tanks which were formerly used to provide abbreviated aeration treatment. These have now been lengthened to provide 4 hr. of aeration at design capacity with 25 per cent returned sludge flow. The two circular final settling tanks of this unit provide an average detention time of 2 hr. at design flows and have the older periphery-type overflow weirs.

The larger activated sludge unit, having a capacity of 52 m.g.d., is entirely new and is partially located on the area formerly occupied by the trickling filters. This unit consists of six double-pass aeration tanks which provide a 4-hr. aeration period at design capacity. The six circular final settling tanks of this unit provide an average detention time of 2 hr. and have a double row of weirs on a cantilevered trough which makes the overflow rate exceptionally low and takes into account the density currents met with in activated sludge sedimentation.

All of the aeration tanks have been provided with swing-arm headers and Saran-wrapped stainless steel tubes in tapered aeration pattern. There are approximately 1,000 air diffusers per tank. Sludge is removed from the final settling tank and returned to the aeration tanks by means of air lifts. All of the final settling tanks have revolving-type mechanical equipment for sludge removal. All waste activated sludge is pumped to the sludge concentration unit for further concentration and separation of sludge solids from the water. The concentration unit consists of four Dortmund-type tanks, each of 50,000-gal. capacity, with center inlet connections and peripheral weir overflows. These tanks were originally built to concentrate the raw sludge pumped from the Easterly plant but became unnecessary for this purpose when it became possible to pump a more concentrated sludge.

Space and connections for two additional aeration tanks and two more final settling tanks have been provided at the larger aeration unit. Additional aeration facilities could also be installed on the east side of the blower building at the older aeration unit if this should become necessary. This would bring the total plant capacity to 100 m.g.d.

The blower building, which houses the air compressors, provides air to both activated sludge units. Two parallel cast iron air mains, one 40 in. in diameter and the other 48 in., are laid in the ground connecting the blower building to the new aeration gallery. There they are connected to a single 60-in. diameter air line which tapers in size as it serves the aeration tanks.

Air for the aeration tanks is provided by six blowers. Four of these units are rated at 11,000 c.f.m. each and two units at 10,000 c.f.m. each, all at 8 p.s.i.g. and 400 r.p.m. The two smaller blowers are units which were originally installed in 1937. Before compression, air is filtered through self-cleaning, viscous-type filters followed by dry filters of the stationary electrostatic charged "throw-away" type.

Three of the blower engines are dual fuel, using sewage gas at 15 p.s.i.g. with a minimum of 7 per cent No. 2 pilot diesel oil. The fourth is a straight high compression, spark-ignited, gas engine using gas at 15 p.s.i.g. All four are five-cylinder engines, rated at 462 h.p. at 400 r.p.m. The fifth and sixth engines, which were installed in 1937, are 8-cylinder, spark-ignited, low compression sewage gas engines, using gas at 2 oz. pressure.

Each is rated at 420 h.p. at 400 r.p.m. In all cases engine oil and jacket cooling water are circulated by engine driven pumps.

The advances that have taken place in the design of gas engines are indicated by the fact that the two original engines, installed during 1937, required 9,297 B.t.u. to produce 1 b.h.p. and were 27.3 per cent thermally efficient. The new engines, installed in 1955, required 6,848 B.t.u. to produce 1 b.h.p. and were 37.1 per cent thermally efficient. Operations so far have required the use of only three engines running simultaneously at full-load speed, which gives about 100 per cent stand-by capacity. Because of the difference in efficiencies, an attempt is made to operate the more efficient engines during times of low gas supply.

A feature of the engine installation is the heat-recovery system, which recovers heat from the jacket water and exhaust gases and uses it to preheat the raw sludge in external heaters before the sludge enters the digestion tanks. The water in the heat-recovery system is circulated by means of electric motor-driven centrifugal pumps. In case of power failure an automatic emergency cooling system, which uses city water, is automatically put in service to keep the diesel gas engines in operation.

Sewage Sampling

Raw sewage is sampled at the detritor-comminutor unit by a hand-operated, pitcher-type, pump. Samples are taken in proportion to flow every 2 hr. Each sample is identified and stored separately in a refrigerator. Individual samples are qualitatively examined by laboratory personnel for oil and combustible liquids and, when it is deemed advisable, quantitative measurements of various kinds are made. Routine sewage analyses are then made on 24-hr. composites. An attempt to use an automatic sampling machine at this location was made but was considered a failure because of stoppages and other difficulties.

The settled sewage leaving the primary settling tanks is automatically machine-sampled in proportion to flow. The effluent leaving each of the two activated sludge plants is automatically machine-sampled using timers to obtain a fixed number of samples each hour.

All of the samplers are of the dipper-refrigerated type and each receives a continuously pumped flow of the liquid to be sampled.

Sewage Metering Facilities

Raw sewage is metered by two Venturi meters in parallel, one of which has a capacity of 90 m.g.d. and the other 110 m.g.d. Means are provided for totalizing the flows of the two raw sewage meters and transmitting the total to three indicating receivers located at various places in the plant.

Settled sewage flow to each aeration plant is metered and recorded. In addition, each aeration tank has individual metering and recording of air flow, aerated sewage flow, and returned sludge flow. The new aeration unit also has totalizing meters on the air flow, aerated sewage, and returned sludge flows of the six aeration tanks of the unit. Waste activated sludge flows at both aeration units are metered by means of purge-type Venturi meters.

Sludge Processing

The fact that the Southerly plant processes all of the sludge produced by the Easterly sewage treatment plant, in addition to its own, has made the sludge-processing units complicated and large (Figure 3). The recent addition of six more heated, floating-cover digesters has brought the total to 18, with a combined capacity of 2,887,500 cu. ft. In addition, the former Imhoff tanks are being used as unheated secondary digesters, without any gas collection facilities, and

FIGURE 3.—Aerial view of the sludge digestion facilities. Imhoff tanks are in the left foreground.

constitute approximately another 1,400,000 cu. ft. of digestion capacity. In all, a total of 4,287,500 cu. ft. of digestion capacity is available for the digestion of about 1,300,000 gal. of raw sludge daily. In terms of equivalent per capita suspended solids capacity, this volume amounts to approximately 2.94 cu. ft. per day per capita.

The new digesters differ from the original 12 principally in that no interior heating facilities are provided; all heating of the sludge is done by circulating digester liquor to two external sludge heaters rated at 1 million B.t.u. output each.

Eight additional external sludge heaters have also been provided to heat all of the raw sludge before discharging into any digester. Each of these heaters is rated at 2.5 million B.t.u. output each. The interior heating coils of the original 12 digesters are still intact and are being used principally to make up heat lost from these digesters. Two separate hot-water heating systems are in use simultaneously to provide the hot water circulated in the coils and sludge heaters. The boiler water system burns gas or fuel oil in standard hot water boilers which produce the hot water which is circulated through all of the heating coils and some of the sludge heaters. The gas engine heat recovery system provides recovered heat from the engines and this water is circulated in the remaining sludge heaters. Although the heating systems are separate, there is a great deal of flexibility so that, as the occasion arises, more or less of the load can be carried by either heating system. Recently all 12 of the hot water boilers were modernized with new safety controls and piping improvements so that the safest possible conditions exist.

At the present time the Imhoff tanks

receive all of the supernatant produced in the heated primary digesters and remove substantial amounts of solids. The supernatant enters the Imhoff tank sludge compartments and the effluent leaves over a weir in the flow-through chamber at the opposite end of the tanks, the liquor rises through the slot connection between the sludge compartment and the flow-through chamber. The tanks are operated in batch fashion and at constant levels. Little money was spent on making the necessary changes to convert the Imhoff tanks to their present use and operations have been more or less experimental in nature. It is expected that operating experiences and performance data now being collected will be of considerable value in the future when decisions must be made as to necessary repairs, changes, and improvements to these tanks. The new sludge pumping facilities at the Imhoff tanks have been fully available only recently and the considerable inventory of sludge in these tanks is now being reduced at a good rate.

The new elutriation unit (Figure 4) was completed a number of years ago, but it is only in the last year or so that it has been possible to operate this unit continuously and to obtain data by which to evaluate it. The elutriation facilities consist of two mixing tanks, designed to provide a mixing period of 2 min., and two settling tanks, designed to provide a settling period of 2 hr. with a 25 per cent reserve sludge storage space. The settling tanks are equipped with sludge-removal mechanisms of the chain-driven straight-line type. These tanks have been designed for countercurrent elutriation of the digested sludge and/or digester supernatant, using final plant effluent for the wash water. The design capacity of the unit is such that 1.2 million gallons of combined digested sludge and supernatant can be washed continuously in a 24-hr. period with approximately 4.8 million gallons of wash water, producing an elutriated sludge with substantially less chemical demand for vacuum filtration of the sludge. In addition, an elutriate of 1,000 p.p.m. or less of suspended solids is to be produced and discharged to the Southerly plant sewage flow.

Although it has not been possible to eliminate the use of lime, the cost of chemicals used per unit volume of sludge has been reduced by about 50 per cent and the total equivalent percentage of ferric chloride on a cost basis amounts to between 4 and 5 per cent. Laboratory Buechner funnel

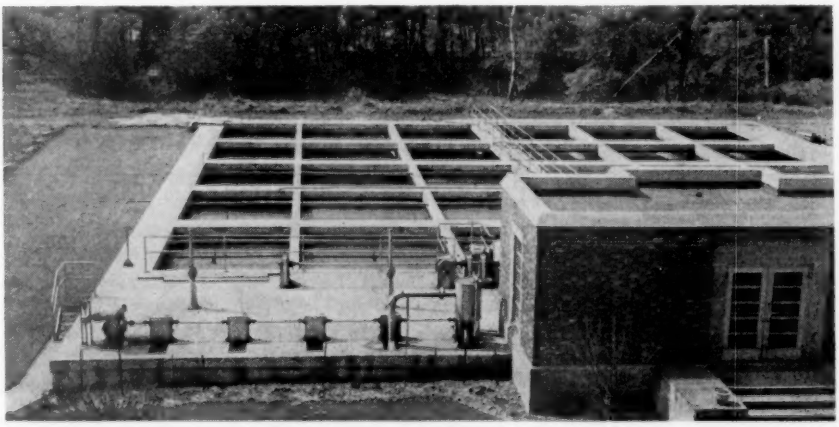

FIGURE 4.—Recently constructed elutriation unit.

tests have confirmed plant operating experiences which indicated that better results are obtained from the use of both lime and ferric chloride as coagulating chemicals.

The wash water used is pumped through a 20-in. force main from the wash water pump house to the elutriation unit. The elutriate leaving the unit overflow weirs enters troughs which extend into the tank. The elutriate is discharged either to the influent conduit of the primary settling tank or to the settled sewage flowing to the aeration units.

The elutriation tanks have a spray-water system to aid in removal of scum solids, and slotted, tilting, scum-removal piping conveys the scum to a pump which returns it to the Imhoff tanks.

No contract improvements have been made to the original vacuum filtration facilities which consist of eight string-type vacuum filters, each having 320 sq. ft. of surface area.

The four sludge incinerators are being improved at the present time by enlargement and additions to the ash system. It is expected that this will permit utilizing the present total 400-ton per day capacity of the incinerators more fully.

Design work is now in progress on another unit for disposing of vacuum filter sludge cake which will probably consist of four vacuum filters and two incinerators of about 250 tons per day capacity.

Acknowledgment

The program of providing adequate sewage treatment for the City of Cleveland, of which construction at the Southerly plant is a portion, is being carried forward under the direction of Mayor Anthony J. Celebrezze, Director Emil J. Crown of the Department of Public Utilities, Commissioner G. E. Flower* of the Division of Sewage Disposal, and Commissioner George W. Hamlin of the Division of Utilities Engineering. The consulting firm of Havens and Emerson designed and supervised the construction of the units.

* Retired.

DELAWARE VALLEY ENGINEERS

A Division of Hydraulics and Sanitary Engineering has been formed by the Philadelphia Section, American Society of Civil Engineers. Meetings will be scheduled for the third Thursday of September and November, 1957, and January, March, and May, 1958, at the Engineers Club, 1317 Spruce St., Philadelphia, Pa.

FROTHING OF SYNTHETIC SEWAGES

By L. A. Munro and M. Yatabe

Sanitary Engineering Laboratory, Queen's University, Kingston, Ontario, Canada

Various factors have been suggested as the cause of frothing in sewage treatment (10). In some instances the frothing has been attributed to the syndets present in the raw sewage, but the relative effect of these detergents in many cases is not fully understood (5)(7)(12)(14). The lack of knowledge in the whole field of induced frothing has been pointed out by Wells (17) who raises the question: "What then is responsible for froth formation and why does increasing the solids in the aeration tanks eliminate frothing?" Gowdy has said (6): "There is no pretense at knowing what makes froth at low solids. Neither is it understood why some plants can operate without froth at lower solids levels than others. It appears that the froth-making agent is actually manufactured right in the tank by the oxidation process."

A standard synthetic sewage has obvious advantages as a medium for the study of the effect of specific factors on the tendency of sewage to froth (4). Many of the variants encountered in experiments with municipal sewage are eliminated.

Experimental Procedure

Several workers (1)(13)(16) have shown that a synthetic sewage may be used to obtain valid results in activated sludge and B.O.D. studies. In the investigation reported in this paper, the synthetic sewage formula used in studies at the Massachusetts Institute of Technology was used as a base; the soap was replaced by other detergents and fat in concentrations as shown in Table I. The weighed amounts of components were made up with tap water (Lake Ontario water having 124 p.p.m. total hardness) to which 1 per cent by volume of raw sewage was added as inoculum.

Four liter quantities were made up in large battery jars and kept in a water bath at 20° to 22° C. Compressed air was introduced through perforated Tygon tubing at the bottom of the jars to provide aeration and keep the mixture gently agitated. The jars were covered to reduce evaporation losses.

The initial frothing ability and the changes in frothing which followed aeration for an extended period were measured using the froth-column apparatus described elsewhere (9). Simultaneous determinations of pH, surface tension, and oxidation-reduction potential were made and reported graphically.

Test Results

Fats

In the series A tests, emulsified fat was added to the basic sewage containing dextrose, starch, and peptone. Figure 1A shows that with formula 1–A–1 (35 p.p.m. of fat) no frothing was obtained during aeration over a period of three weeks. The same result was obtained when the fat concentration was increased 10-fold (10–A–1). However, when the concentration of the non-fat components was increased 10-fold (1–A–10), a sharp rise in the amount of froth occurred at one-day aeration time. The froth curve then showed a dip, followed by a steady rise to a maximum at the end of seven days of aeration.

TABLE I.—Composition of Synthetic Sewage Mixtures

Sewage Test	Synthetic Sewage: Components (p.p.m.)							B.O.D. (p.p.m.)
	Dextrose[1]	Starch[2]	Peptone[3]	Soap[4]	Sodium Lauryl Sulfate[5]	Fab[6]	Fat[7]	
1-A-1	75	75	75	—	—	—	35	185
10-A-10	750	750	750	—	—	—	350	1,696
1-A-10	750	750	750	—	—	—	35	1,448
10-A-1	75	75	75	—	—	—	350	636
1-A-5	375	375	375	—	—	—	35	—
1-B-1	75	75	75	—	37.5	—	—	248
10-B-10	750	750	750	—	375	—	—	1,544
1-B-10	750	750	750	—	37.5	—	—	1,460
10-B-1	75	75	75	—	375	—	—	1,160
1-C-1	75	75	75	37.5	—	—	—	192
10-C-10	750	750	750	375	—	—	—	1,560
1-C-10	750	750	750	37.5	—	—	—	1,332
10-C-1	75	75	75	375	—	—	—	576
1-D-1	75	75	75	—	—	30	—	158
10-D-10	750	750	750	—	—	300	—	1,308
1-D-10	750	750	750	—	—	30	—	1,220
10-D-1	75	75	75	—	—	300	—	612
1-H-1	75	75	75	10	10	—	17.5	164
10-H-10	750	750	750	100	100	—	175	1,420
1-H-10	750	750	750	10	10	—	175	1,368
BL-1	75	75	75	—	—	—	—	—
BL-10	750	750	750	—	—	—	—	1,190

[1] Fisher Scientific Co., anhydrous (d-glucose).
[2] B.H.D. Analar soluble starch.
[3] Difco bacto-peptone.
[4] Lux soap powder.
[5] Eimer and Amend, purified.
[6] Concentration in p.p.m. active agent. Degens-Jones analysis of commercial product gave 29 per cent alkyl aryl sulfonate by weight.
[7] Fat added as emulsion containing cotton seed oil (20 g. per liter), stearic acid (15 g. per liter), triethanolamine (1.7 g. per liter).

When the fat content was also increased 10-fold (10–A–10), a much smaller initial froth rise was obtained, but after the second day's minimum the froth increased with aeration, reaching approximately the same value as when the concentration of non-fat components was increased 10-fold (1–A–10). This suggested that the fat had a depressing effect on froth production. The curves (Figure 1) indicate that a high concentration of non-fat components is responsible for the secondary increase in frothing tendency.

A further experiment was set up in which the sample of synthetic sewage contained one unit of fat and five times the unit concentration of non-fat components. Although the inoculating sewage was not the same as in the previous experiments, the curve obtained (1–A–5) is quite similar in appearance to those for higher total solids. The initial froth height was 0 cm., with a high frothing tendency after one day of aeration. A second maximum occurred at six days. This maximum froth height was lower than the maxima with the A–10 samples.

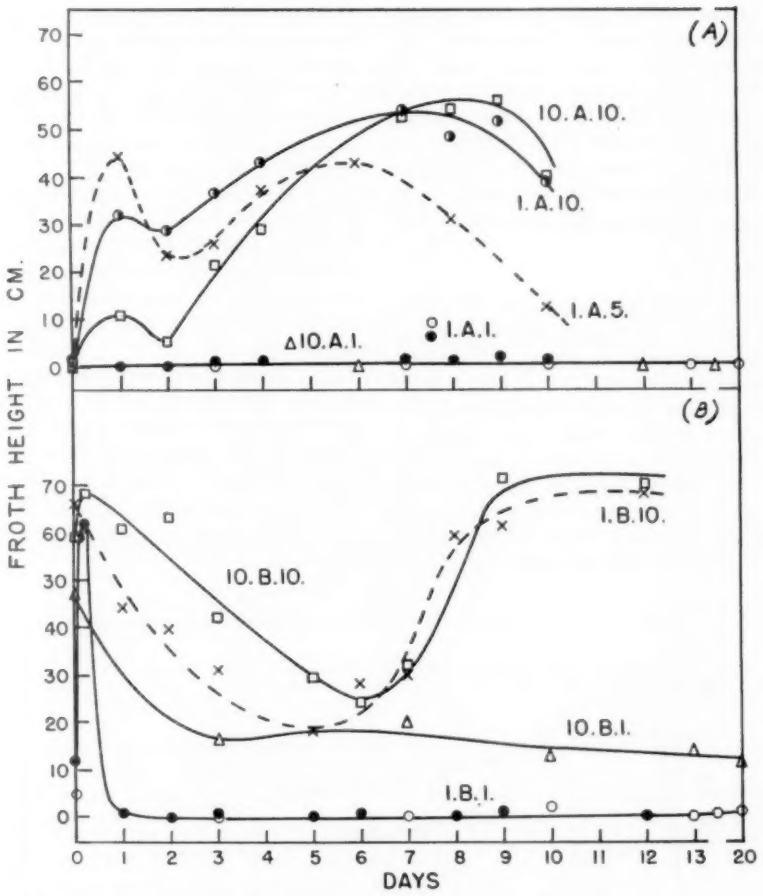

FIGURE 1.—Frothing ability of synthetic sewages containing (A) fat and (B) sodium lauryl sulfate.

Sodium Lauryl Sulfate

Figure 1 B shows the results obtained when sodium lauryl sulfate, an anionic detergent, was substituted for fat in the sewage formulation (B series). Duplicate experiments (1–B–1) using a unit concentration of 37.5 p.p.m. of the detergent indicated a modest initial froth which increased sharply during the first 2 to 4 hr. of aeration after which it dropped to zero and remained constant for the rest of the aeration period.

Increasing the amount of sodium lauryl sulfate in the sewage 10-fold caused a big increase in the froth formation (10–B–1). The high initial froth value decreased sharply during three days of aeration and thereafter it decreased very slowly. Some frothing ability remained after 20 days of aeration.

When the non-detergent constituents were increased 10-fold (1–B–10), the initial frothing ability was also increased. The tendency to froth decreased to a minimum after five days

of aeration and then it increased as aeration continued. This action was similar to the experiments with the concentrated sewage containing fat. Additional sodium lauryl sulfate caused still greater froth formation at zero time, a longer period of aeration to reach the minimum, and more frothing on extended aeration (10–B–10).

Soaps

It might be expected that the frothing behavior of sewage containing soap would resemble the action of a sewage which contains equivalent amounts of fat, particularly in the presence of hardness in the water. In Figure 2, curves 1–C–1 and 10–C–1 are similar in that froth did not develop with continued aeration. When the non-soap constituents were increased 10-fold (the soap concentration being held at 37.5 p.p.m.) a rapid increase in frothing of the sewage took place on aeration during the first 24 hr. The froth then decreased in a somewhat irregular manner to a 12-day value of 24 cm. (1–C–10). Increasing the concentration of soap 10-fold (10–C–10) again resulted in no initial froth but froth was induced on aeration. The frothing ability of this sample was consistently lower than with the unit concentration of soap (1–C–10). This is a similar effect to that observed with the fat (Series A).

The experiments were repeated by another laboratory, using a different inoculum. The results (open circles, Figure 2) are plotted with the earlier duplicate runs. While the absolute values for froth production differ, the general observations were borne out in both cases.

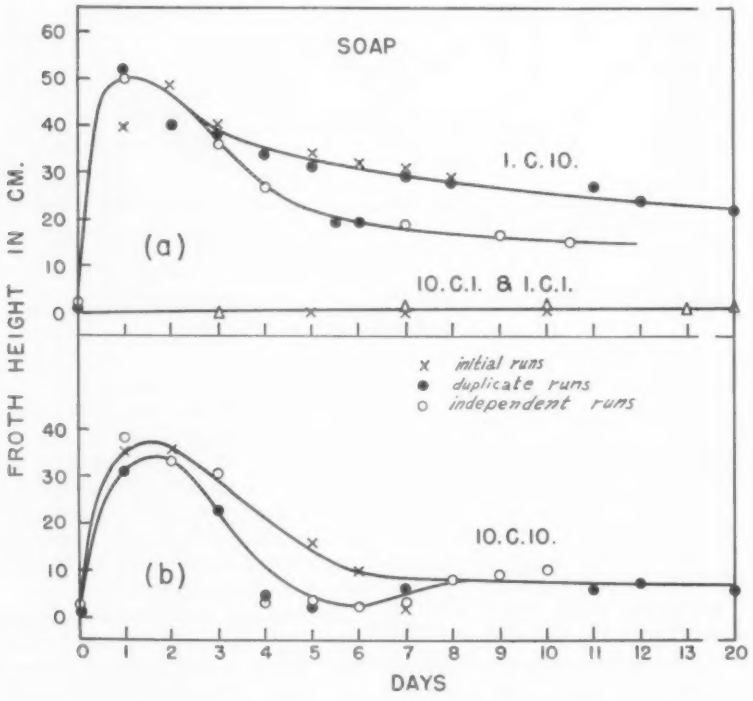

FIGURE 2.—Frothing ability of synthetic sewages containing soap.

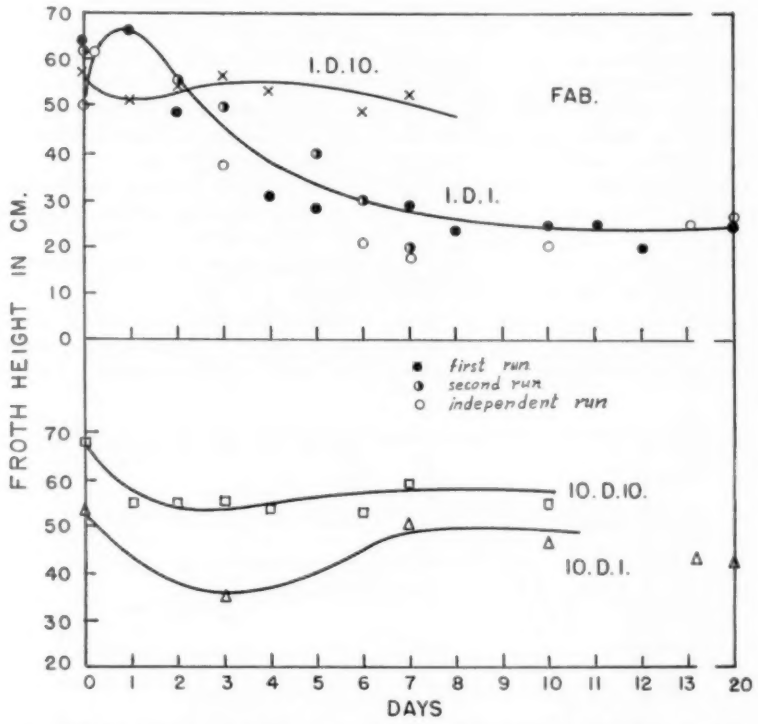

FIGURE 3.—Frothing ability of synthetic sewages containing a syndet, Fab.

Alkyl Aryl Sulfonate

In test series D (Figure 3), sufficient amounts of Fab were used so the sewage contained either 30 or 300 p.p.m. of active agent. Fab is a fortified alkyl aryl sulfonate. In this series a good initial froth formation was obtained with a unit concentration (30 p.p.m.) of the syndet. Curve 1–D–1 gives the mean froth height for three separate runs. Although this type of surface active agent is more stable than sodium lauryl sulfate, a decrease in froth height was observed, followed by steady values of 20 to 25 cm.

In contrast to the curves for fat- or soap-containing sewages, test 10–D–1 exhibited an increased frothing ability which became stable at values of 42 cm. after 10 days of aeration.

As with sodium lauryl sulfate a higher total solids content in the sewage gave a higher froth, both initially and after seven days of aeration.

Mixtures

The synthetic sewage in test 1–H–1 contained 10 p.p.m. of soap, 10 p.p.m. of sodium lauryl sulfate, 17.5 p.p.m. of fat, and standard amounts (75 p.p.m.) of peptone, starch, and dextrose. No appreciable quantities of froth were observed in duplicate experiments during aeration (Figure 4).

Sewage 10–H–10 with ten times the quantities of each component gave a curve which resembled the 10–A–10 curve. Both curves had an initial rise from a low froth value, followed by a minimum and then an increasing froth height after two days of aeration.

In sample 1–H–10 the concentration of detergents was kept at 10 p.p.m.

each, and the fat and other components were increased 10-fold. The frothing characteristics of this sewage also resemble those of the A series, although the one-day maximum was higher. In both of the latter experiments the stable frothing values were greater than with the soap-containing sewage of test series C.

Blank Runs

Blank runs on the aeration of unit and 10-fold concentrations of basic sewage containing no fat or detergents are also plotted in Figure 4. It is noteworthy that whereas the unit quantities gave no froth initially nor during continuous aeration, the higher concentration of non-detergents resulted in a good stable froth. The froth production reached a constant value after aeration for one week.

The relation between the concentration and frothing ability of peptone sols only is shown in Table II. Froth formation starts at approximately 200 p.p.m.

Dextrose alone and starch alone in concentrations of 750 p.p.m. produced less than 1 cm. of froth. Combined

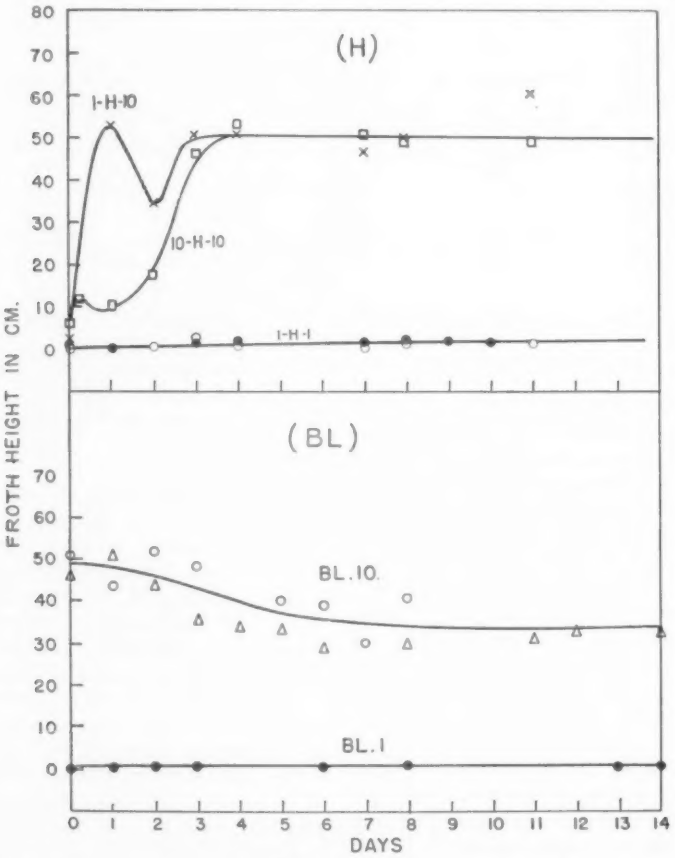

FIGURE 4.—Frothing ability of synthetic sewages containing mixed detergents (H) and no detergents or fats (BL).

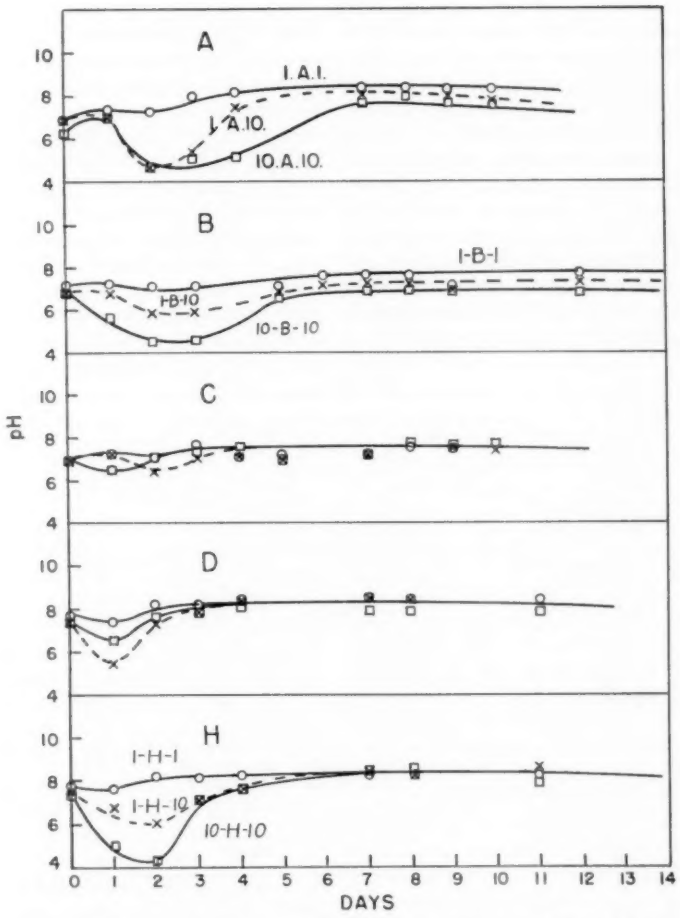

FIGURE 5.—Changes in pH of synthetic sewages during aeration.

sols containing 750 p.p.m. each of peptone-dextrose or peptone-starch gave the same initial froth formation as peptone alone.

TABLE II.—Frothing of Peptone Sols

Peptone (p.p.m.)	Froth Height (cm.)
75	0.0
150	0.0
300	4.3
450	15.5
600	25.1
750	62.1

pH and Surface Tension

The pH values in each series are given in Figure 5 and the corresponding surface tension curves are given in Figure 6. Surface tension is reported as dynes per centimeter at 20° C.

Discussion

One of the reasons Gowdy (6) gives for not believing that syndets are the usual cause of frothing in aeration tanks is that "Detergents and other sudsing agents produce suds at once, not after a period of aeration." The

results reported herein support this observation in that only those unit synthetic sewages (total solids content of approximately 265 p.p.m.) which contained syndets gave any initial froth. During aeration the frothing ability decreased within a few hours (sodium lauryl sulfate) or at most within one day. However, the sewage containing 30 p.p.m. of active sulfonate (1–D–1) showed appreciable froth at all times in spite of an initial decrease. This type of syndet has been shown to be resistant to oxidation (2)(11).

One of the interesting conclusions from these experiments is that fat and the calcium and magnesium soaps have a depressing effect on the frothing tendency of the sewage. This is clearly indicated by a comparison of curves 1–A–10 and 10–A–10 (Figure 1) and 1–C–10 and 10–C–10 (Figure 2). In an additional experiment, a sol containing 750 p.p.m. of peptone and 350 p.p.m. of emulsified fat, with one per cent by volume of inoculum as in the other synthetic sewages, was found to have no froth, whereas the peptone

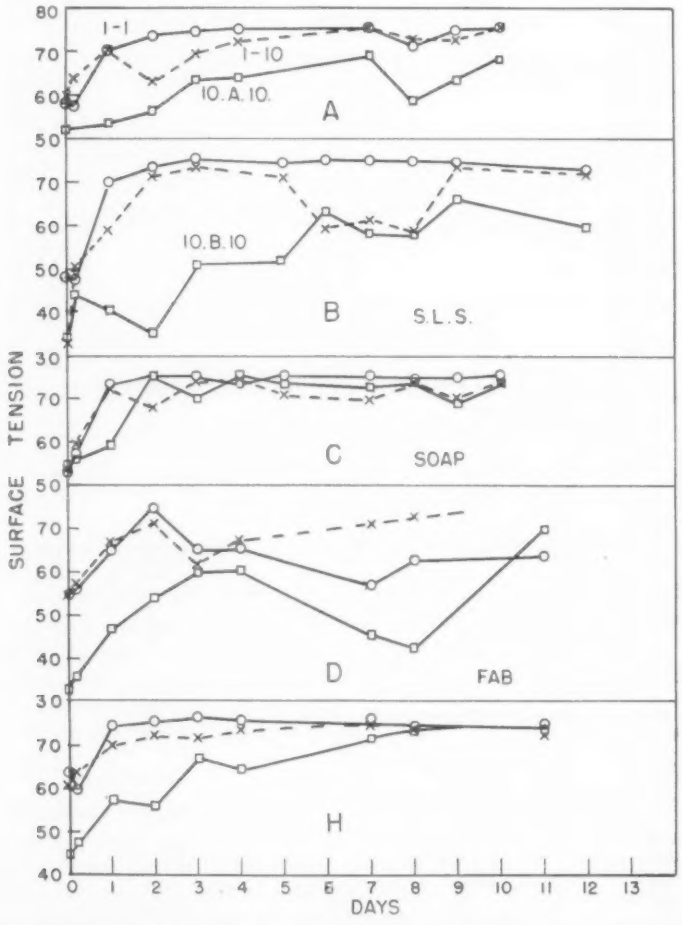

FIGURE 6.—Surface tension changes of synthetic sewages during aeration.

alone with inoculum gave 62 cm. of froth.

A further run was made in which a complete synthetic sewage containing 350 p.p.m. of fat was aerated for three days. Analysis showed that the fat content had decreased to 158 p.p.m. During this time the frothing ability had increased from 0 cm. to 11.2 cm. of froth height. The fat content then was adjusted to give the original concentration. Froth measurements of the sewage indicated 0 cm. of froth.

In another experiment in which the froth height increased from 0 cm. to 21.5 cm. in six days, the replacement of the depleted fat reduced the froth height to 5.7 cm. The addition of more fat reduced the froth to 2.8 cm. but not to 0 cm. It is possible in this case that aeration formed so much of the "something that produces frothing" (17) that the "something" is not completely adsorbed or otherwise removed by the emulsified fat.

Control of frothing by maintaining a high suspended solids content in the sewage is current practice (18). The effect is probably one of adsorption (4)(5)(15). It has been shown, however, that a suspended solids content greater than even 1,400 p.p.m. is sometimes incapable of preventing frothing (8).

The blank experiments indicated that neither sugar nor starch in the concentrations used was the cause of secondary frothing. It appears that the froth which developed most strikingly in series A, C and H was due to oxidative changes which took place in the nitrogenous material. The extent of the froth development depended on the concentration of this material and also on the nature of the other sewage components and their oxidation products.

pH

Froth formation is dependent on the pH of the sewage. In this regard Eckenfelder and Hood (3) state that frothing due to aeration of domestic sewage occurs towards the end of the carbonaceous cycle in a zone of high pH (8.12 to 8.35). Figure 5 shows that in the A–10 and H–10 series there were sharp decreases in pH between the first and second day of aeration, to values close to the isoelectric point of the peptone. Minimum froth formation corresponded to this point. Thereafter, both the pH and froth increased. The B–10 test series also showed a decrease in pH, and the minimum froth height occurred after 2 to 3 days of aeration. However, in this series, minimum froth does not correspond to minimum pH; in fact, when the frothing ability was at a minimum, the pH had increased to approximately 7. Furthermore, the minimum in pH for the D series was not reflected by the height of the froth. The marked increase in froth production on aeration of the soap series was not paralleled by any such increase in pH. The pH of the blank BL–10 showed a slight decrease in pH from 7.5 to 6.8, then a gradual increase to pH 8.4, during which time the frothing ability showed a gradual decrease.

Measurements of the oxidation-reduction potentials of all mixtures with a high solids content showed sharp minima at between one and two days of aeration. In the A–10 and C–10 curves (Figures 1 and 2, respectively) the minimum values were electronegative. All sewages with unit concentrations showed a gradual decrease in positive values.

There appears to be no relation between surface tension and frothing ability.

Total Solids

It will be noted that the sewages containing syndets and high total solids gave stable froth values higher than those of the blanks which contained the same original amounts of dextrose, starch, and peptone. The rapid oxidation of sodium lauryl sul-

fate is reflected in the rapid decrease in frothing ability. The pH is also reduced.

The subsequent rapid increase in frothing ability would suggest that the new frothing material is not dependent entirely on the peptone. Furthermore, the fact that all the other concentrated sewages, except the one containing soap, reached secondary froth height greater than the blank, suggests that the non-detergent constituents or decomposition products act as stabilizing agents for the froth. With soap, maximum induced frothing was reached with one day of aeration.

Summary

The frothing characteristics of a series of synthetic sewages having a base of dextrose, starch and peptone with additions of fat, sodium lauryl sulfate, soap, alkyl aryl sulfonate, or mixtures, were determined using a froth column (9). Samples were inoculated with 1 per cent by volume of raw domestic sewage and aerated continuously for periods up to 20 days. With sewage having a high total solids content, the shape of the curves for frothing ability was controlled by the nature of the added constituent. Sewages containing emulsified fat or soap gave no initial froth formation, but they developed froth on aeration. The fat showed a high maximum froth after one week of aeration and the soap gave a lower maximum after 24 hr. Syndet froth curves showed high initial froth values which decreased on aeration, but some subsequently increased again on prolonged aeration.

Synthetic sewage containing 75 p.p.m. each of dextrose, starch, and peptone, with (a) 37.5 and 375 p.p.m. of soap and (b) 35 and 350 p.p.m. of fat, showed practically no tendency to froth at any time. Sodium lauryl sulfate (37.5 p.p.m.) in a similar sewage base gave a temporary increase in froth formation after aeration for 2 to 4 hr. with no frothing after one day. Fab (30 p.p.m. active sulfonate) had considerable frothing ability which decreased but was still appreciable after 20 days of aeration.

Emulsified fat and the lime and magnesium soaps acted as anti-froth agents for the secondary frothing substances which develop on aeration.

This study did not evaluate the role of activated sludge solids which varies in practice with the amount, chemical, physical, and biological nature of the sludge.

Acknowledgment

The above investigation was made possible by a grant from the Ontario Research Council to the Sanitary Engineering Laboratory of the Department of Civil Engineering, Queen's University, Kingston, Ontario, Canada.

The interest and help of Professor J. D. Lee are sincerely appreciated.

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UNITS OF EXPRESSION COMMENTS INVITED

In the February, 1957 issue of THIS JOURNAL the readership was invited to comment on the paper "Preliminary Report on Recommended Units of Expression for Design and Operation of Sewage and Industrial Wastes Treatment Plants" (**29**, 2, 134). This report, otherwise known as the "Units of Expression" report, was prepared, under the Chairmanship of Dr. H. E. Orford, by the Subcommittee on Standardization of Units of the Committee on Sewage and Industrial Wastes Practice.

Comments to date have ranged from approval to absolute rejection, and the committee members are grateful to all who have responded. However, the "Standardization" Committee is anxious to have all possible comments by early September, in order to prepare a progress report for the Federation Board of Control meeting at Boston in October. All readers of the Journal are invited to submit their constructive comment and criticism. In this way the Federation will be helped in making a vital decision which could affect the future activities of all those in the field of sanitary engineering. Response may be made either to the Federation Executive Secretary, Washington, D. C., or to Dr. H. E. Orford, Rutgers University, New Brunswick, N. J.

Industrial Wastes

DETERMINATION OF THE CHEMICAL OXYGEN DEMAND OF CITRUS WASTE WATERS*

By Robert R. McNary, Marshall H. Dougherty, and Richard W. Wolford

Florida Citrus Experiment Station, Lake Alfred, Fla.

During investigations carried out in this laboratory on the treatment of citrus wastes, the 5-day B.O.D. and the total, fixed and volatile solids have been used as the means of evaluating the thoroughness of the treatment. This method was quite satisfactory on a laboratory scale where the raw waste was made by diluting citrus juices a predetermined amount, thereby producing a uniform raw waste. In later work on a pilot-plant scale, where actual processing plant wastes were being treated, the great variability of the strength of these wastes made it highly desirable to determine their strength quickly in order to adjust treatment operations to the current situation. The use of a biological procedure for this purpose is not suitable because of the time required to obtain the results.

Several chemical oxygen demand procedures have been published that might be suitable. Probably the most rapid procedure is that of Porges *et al.* (1). This procedure has several disadvantages. The method of heating the reaction mixture is hard to control and the constant attention of the analyst is required. In the laboratory it was found difficult to heat the mixture uniformly to 165° to 170° C. in 5 to 6 min., especially in the summer time; with open windows, varying air currents changed the rate of heating continually. Another disadvantage stems from the fact that the potassium dichromate is dissolved in a mixture of sulfuric and phophoric acids. This solution is viscous and it is difficult to measure out the correct amount volumetrically. The authors found that blank determinations varied appreciably for this reason.

The procedure of Moore *et al.* (2) (3) has the disadvantages of the somewhat lengthy reflux period of 2 hr. and the fact that the titrating solution must be standardized each day. Otherwise this procedure is satisfactory. The directions for this procedure state that the reflux period can be shortened when it can be demonstrated by experiment that a shorter period will give satisfactory results with the particular type of waste being analyzed. The time required in the case of citrus waste water has not been published heretofore. The minimum reflux time was therefore investigated by determining the change in chemical oxygen demand of two synthetic waste water samples made from canned orange juice diluted with tap water when

* Cooperative research by the Florida Citrus Commission and Florida Citrus Experiment Station. Florida Agricultural Experiment Station Journal Series, No. 611. Presented before the Division of Water, Sewage and Sanitation Chemistry, at the 131st Meeting, American Chemical Society; Miami, Fla.; April 7–12, 1957.

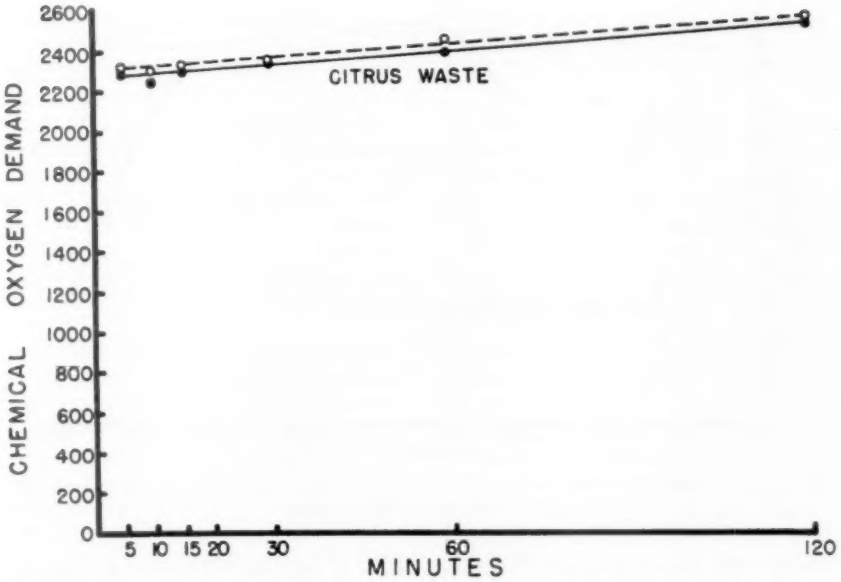

FIGURE 1.—Relationship between chemical oxygen demand value and time of reflux.

the reflux time varied from 5 to 120 min. The results are shown graphically in Figure 1.

It was apparent that citrus wastes were quickly oxidized by the dichromate. In these two instances, over 90 per cent of the final 2-hr. C.O.D. value appeared in the first 5 min. It was arbitrarily decided, however, to standardize on a reflux period of 10 min. for citrus wastes since an error in timing the period would then be less likely to affect the result.

Test Procedures

Three titrations are necessary for the determination of the chemical oxygen demand of a single sample of waste by the Moore method. One titration is required to determine the normality of the ferrous ammonium sulfate solution and this must be repeated each day. The second titration is required for the blank and the third for the sample itself. Some of this manipulation might be avoided if the result could be obtained by colorimetry rather than by titration.

Colorimetry

To determine whether the color change, when the dichromate solution is reduced, is adequate for colorimetric analysis, a solution corresponding to the blank determination of the Moore procedure was placed in a Beckman DU spectrophotometer and the absorption spectrum in the visible region determined. The absorption spectrum was also determined on another potassium dichromate-sulfuric acid-water mixture in which sufficient sucrose was added before refluxing to reduce completely the dichromate present.

The spectral transmission curves of these two solutions are shown in Figure 2. At 650 mμ., the transmission of the reduced chromate was 52 per cent of the transmission of the unreduced chromate. That this difference was ample for use in the colorimetric assay of the strength of citrus waste

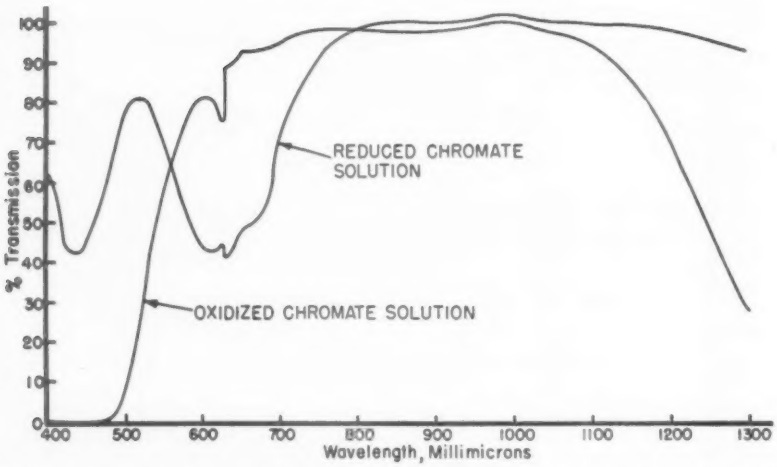

FIGURE 2.—Spectral transmission curves of dichromate oxidizing mixture in original (oxidized) and reduced forms.

waters was demonstrated by adding increasing amounts of the citrus waste to the reflux mixture and reading the transmission in a photoelectric colorimeter. These results are shown graphically in Figure 3.

To translate the per cent transmission obtained from photometer readings to oxygen demand values, a standard curve was prepared (Figure 4). A solution of sugar containing exactly 2.0 g. per liter was made from a sample of National Bureau of Standards sucrose that had been dried for a week in a vacuum desiccator. From 1.0 to 25.0 ml. of this solution was measured by burette into a round-bottomed 500-ml. flask, diluted to 50.0 ml. with distilled water also measured in a burette. The usual quantities of

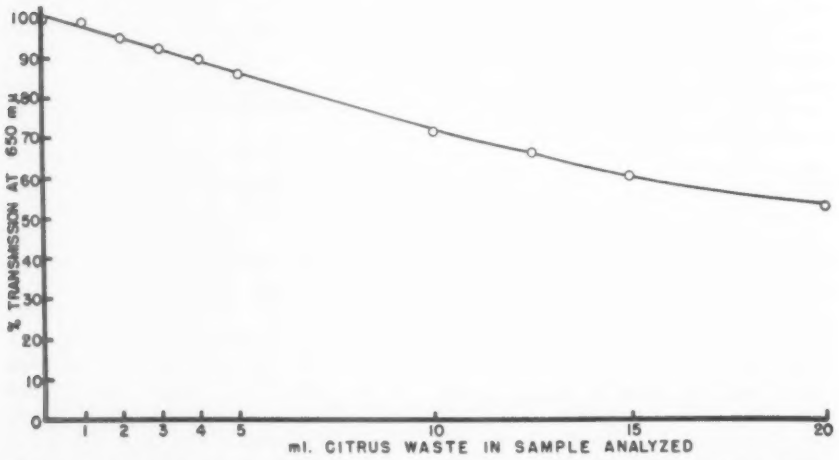

FIGURE 3.—Per cent transmission at 650 mμ. of samples containing increasing amounts of citrus waste water.

dichromate solution and sulfuric acid were added and the mixture was refluxed for 10 min. The flask was removed from the reflux apparatus and cooled to room temperature in a running-water bath. A portion of the liquid was placed in a 3-ml. cylindrical cell and the optical transmission at 650 mμ. determined in a Fisher electrophotometer. A blank sample containing no sugar was used to adjust the instrument to read 100 per cent transmission.

To eliminate the necessity of preparing a blank determination each time a sample is analyzed, a blank solution was sealed in one of the glass cells used in the Fisher electrophotometer. As far as can be determined, this solution has not changed its light transmission at 650 mμ. in a year. Using this permanent blank, the complete oxygen demand determination can be carried out in about 20 min.

Comparison Standards

Since the sealed blank was apparently stable, it appeared possible that a set of comparison standards could be prepared which would also be stable. If successful, the determination of the chemical oxygen demand could then be made by visual comparison of the color of the refluxed mixture with the standards. The necessity of having a colorimeter would be removed.

To test this hypothesis, a solution of sucrose containing exactly 2.0 g. per liter was prepared as before. Theoretical quantities of this solution were measured out with a burette to give a series of samples containing from zero to 1,500 p.p.m. C.O.D. in increments of 50 p.p.m. Sufficient water was added to bring the volume up to 50 ml.; then 25 ml. of potassium dichromate solution and 75 ml. of sulfuric acid were added and the mixture was refluxed for 10 min. After cooling, the resulting solutions were sealed in 25-mm. diameter test tubes.

The colors ranged from the amber of the zero-oxygen-demand tube to a blue-green in the 1,500 p.p.m. chemical-oxygen-demand tube. Against a white background and with good light, such as provided by a fluorescent titration illuminator, the differences between adjacent tubes could be readily distinguished. One exception should be noted; the color difference between the 50 p.p.m. tube and the 0.0 p.p.m. tube was slight and extra care must be taken to provide uniform lighting.

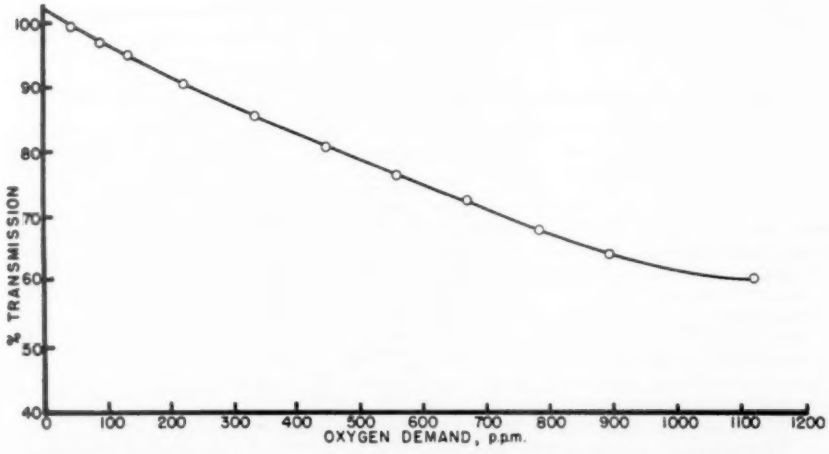

FIGURE 4.—Reference curve for converting photometer readings to C.O.D. values.

TABLE I.—Comparison of Oxygen Demand Analyses of Citrus Waste Water and Citrus Activated Sludge Effluent

Raw Citrus Waste				Citrus Activated Sludge Effluent			
5-Day B.O.D. (p.p.m.)	Standard Methods C.O.D. (p.p.m.)	Colorimetric C.O.D. (p.p.m.)	Visual Comparison C.O.D. (p.p.m.)	5-Day B.O.D. (p.p.m.)	Standard Methods C.O.D. (p.p.m.)	Colorimetric C.O.D. (p.p.m.)	Visual Comparison C.O.D. (p.p.m.)
1,295	2,290	2,450	2,375	4.0	45	55	—
1,330	2,310	2,500	2,375	6.7	55	70	—
1,400	2,295	2,350	2,250	5.0	66	70	50
1,630	2,330	2,475	2,355	6.1	52	70	50
1,705	2,285	2,500	2,355	5.7	42	65	50
1,565	2,240	2,375	2,375	6.6	51	70	50
1,385	2,300	2,490	2,375	3.4	34	30	50
1,410	2,270	2,375	2,375	3.6	26	60	50
1,220	2,175	2,350	2,250	5.8	20	60	25
1,680	2,300	2,350	2,375	3.0	31	40	25
AVERAGE							
1,462	2,280	2,422	2,346	5.0	42	59	44

This set of sealed, color-comparison tubes has been in existence for 10 months. When not in use the tubes are stored away from daylight. Thus far no changes have been noticed in the colors and it is hoped that they will prove to be permanent.

Data

Raw citrus waste water was made by diluting orange juice with a suitable amount of tap water. This was treated in a laboratory activated sludge unit described previously (4). A series of samples of the raw and treated waste water were analyzed for 5-day B.O.D. and for C.O.D. The C.O.D. analyses were made by three methods: (a) the procedure of Moore with the full 2-hr. refluxing and titration; (b) the quick method proposed herein with 10-min. refluxing and colorimetry; and (c) the quick method with 10-min. refluxing and visual comparison with sealed standards. The data are shown in Table I. The ratios of the averages of these 10 samples when analyzed by different procedures are given in Table

TABLE II.—Ratios and Statistical Correlations of Analyses by Different Procedures

C.O.D. Comparison	Raw Citrus Waste			Citrus Activated Sludge Effluent		
	Ratio	Correlation Coefficient	No. of Samples	Ratio	Correlation Coefficient	No. of Samples
Std. Methods C.O.D. *vs.* B.O.D.	1.56	0.4346*	23	8.40	0.4699*	20
Colorimetric C.O.D. *vs.* B.O.D.	1.66	0.4669*	23	11.80	0.4496†	17
Visual C.O.D. *vs.* B.O.D.	1.60	0.2639†	19	8.80	0.6780‡	15
Colorimetric *vs.* Std. Methods C.O.D.	1.06	0.3113†	31	1.40	0.4305*	24
Visual *vs.* Std. Methods C.O.D.	1.03	0.0973†	26	1.05	0.6255‡	21
Colorimetric *vs.* Visual C.O.D.	1.03	0.0325†	26	1.34	0.4218†	21

* Significant correlation at 5 per cent level.
† Correlation not significant at either 1 or 5 per cent levels.
‡ Significant correlation at 1 per cent level.

II. All of the data obtained on the analyses of samples by the different procedures were examined statistically. The correlation coefficients and the degree of significance are also shown in Table II. The degree of significance was determined according to the method of Snedecor (5).

Discussion

The objective of this investigation was not to develop an analytical procedure for determining the strength of citrus wastes that would replace the procedures already available. There is no substitute for the 5-day B.O.D. determination and none of the chemical procedures measure the same substances in the same manner that it does. There is, however, a definite place for the C.O.D. test, particularly when only one type of waste is under consideration.

Excellent discussions on the relationships between B.O.D. and C.O.D. data may be found in the literature (6) (7). Citrus wastes, being predominately carbohydrate in nature, are readily oxidized by either chemical or biological means. The results determined by the two procedures are considerably different. The C.O.D. values obtained by the Moore procedure were, on the average, 1.56 times greater than the B.O.D. values. As long as a citrus waste sample is not contaminated with another kind of waste, this factor may be used to estimate the B.O.D. value from the C.O.D. analysis with fair accuracy. When a different type of waste is being analyzed, different ratios must be used as illustrated by the effluent ratios in Table II.

When some of the accuracy of the Moore procedure may be sacrificed in favor of greater speed and less manipulation, the colorimetric procedure described herein can be used. The colorimetric results were higher than the titration results by a factor of 1.06. This factor could be used when it is desired to compare results obtained by the two procedures. The difference arises from the use of the potassium dichromate solution as a primary standard in the titration procedure and the use of the sucrose solution as a primary standard in the colorimetric procedure.

The authors used the Fisher electrophotometer for the preparation of the standard reference curve and for the analyses mostly because it was felt that a filter-type instrument of this sort would more likely be used by industrial laboratories of citrus processing plants. A few trials indicated that greater precision could have been obtained in a prism-type instrument, such as the Beckman DU, and possibly by other instruments. Greater precision could also have been obtained by using a 25 mm.-diameter instead of a 10 mm.-diameter cuvette when the C.O.D. value was low. This would require the use of a separate reference curve.

When an instrument is not available, a fairly good approximation of the C.O.D. value can still be obtained by visual comparison of the refluxed liquor with standards sealed in glass. It is assumed that these standards will be stable over a long period of time. Periodic checking will be necessary to confirm this.

Whether the analytical results are obtained by titration, colorimetry, or visual comparison, the presence of chlorides and aliphatic organic acids affect the results in the same manner. The reader is referred to the literature (2) (4) (6) for a discussion of this subject. In the analysis of citrus waste waters in Florida, usually these effects are not important.

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ABSTRACTORS NEEDED

Each day much interesting material comes to the Editor's desk. It may be in the form of an interesting article in a well-known publication, a government or university bulletin, or a foreign technical journal. Some of this material is of either general or specific interest to the readers of SEWAGE AND INDUSTRIAL WASTES. To bring this material to Journal readers requires considerable help from interested individuals who have the time and professional enthusiasm to read and abstract so that others might benefit.

An open invitation is extended to those who might be interested in abstracting. Please contact the Editor, expressing your particular interest in the sewage and industrial wastes field. If you have a foreign language specialty please mention it.

WASTE TREATMENT IN THE ATOMIC AGE*

By Kenneth S. Watson

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Everyone reacts to the words "atomic energy" either with fear or hope; fear of its destructive force when used as a weapon; hope for its tremendous potential as a new source of energy for peacetime use. Perhaps the best chance of learning to live constructively with this awesome force is to analyze its significance in each area of endeavor. Changes and innovations, in keeping with this analysis, can then be made in each field of activity to direct the force of the atom toward the ultimate betterment of mankind.

The utilization of atomic power presents special problems in the field of sewage and industrial wastes. This is one of the areas where innovation and broadened effort are essential if the realities of an atomic age are to be faced. Specifically, techniques must be developed to render inoffensive the wastes from atomic industry.

The Responsibility of Industry

An industry which proposes to operate an atomic energy facility should take every possible precaution to prevent the operation from creating a community hazard. Such a policy is dictated by considerations of good corporate citizenship and enlightened self-interest. A responsible industry will utilize all the technical know-how at its disposal and draw on the operating experience of the Atomic Energy Commission in its efforts to safeguard the public.

A number of steps are being taken to control the undesirable effects of an atomic energy operation. These include the following:

1. Installation of large reactors inside a sphere or other enclosure to contain radioactivity in case of an emergency.
2. Establishment of health-physics or radiological sciences laboratories, staffed with qualified personnel, whose function will be to define background conditions and continuously evaluate the effect of the operation on the environment in which the atomic facility is located.
3. Maintenance of monitoring equipment and development of techniques to insure that the level of radioactivity in liquid and atmospheric discharges is maintained in the proper range.

Government Regulations

While it may be assumed that a responsible industry will have a natural compulsion to operate as a good citizen in the community, there are further safeguards, in the form of government regulations, which serve to protect the population against possible ill effects arising from a widespread use of atomic energy.

The Atomic Energy Commission has issued regulations outlining the procedure which an industry must follow in establishing an atomic energy plant. Before construction on such a plant may be undertaken, a "Hazards Summary Report" must be made out and transmitted to the Commission. The report must contain a description of the proposed process, the site, the waste disposal facilities, and many other pertinent data. The Commission reviews the report and, if the installa-

* Presented at the 1956 Annual Meeting, Florida Sewage and Industrial Wastes Assn.; Daytona Beach, Fla., Nov. 12–14, 1956.

tion is of a routine nature and planning is satisfactory, issues a construction permit. Proposed installations which are more complex require the counsel of the Advisory Committee on Reactor Safeguards, a group of recognized experts in the field. The Atomic Energy Commission abides by the recommendations of this Committee.

After determining that the proposed facility meets the standards and requirements of the Atomic Energy Act and that other pertinent agencies have been duly notified, the Commission issues a license. Sometimes the license is withheld until the facility is actually tested for health and safety conditions. Once the license has been granted, each facility must maintain whatever records and reports the license requires. Inspection of the installation by AEC representatives is authorized at any time and routine inspections are also made.

In addition to the Atomic Energy Commission, which has primary responsibility in regulating atomic energy installations, many other federal agencies have some jurisdiction in this field. Among these agencies are the Public Health Service, Interstate Commerce Commission, Food and Drug Administration, and the Postal Service.

At state level, too, atomic energy plants may have to meet the requirements of the health and safety agencies. Thus far, only three states (New York, California, and Texas) have actually passed codes regulating the handling of radioactive materials, although it is understood that Pennsylvania may adopt such a code in the near future. However, in many states atomic energy plants are controlled to some degree by several agencies, including the State Department of Health, the Water Pollution Control Commission, the Conservation Commission, and the Department of Labor.

In many areas atomic energy plants, in addition to having to comply with state and federal requirements, also fall under the jurisdiction of an interstate commission.

Advisory Committees

All industries operating in the atomic energy field have available to them the suggestions and recommendations of some very competent, expert committees. At international level, there is the International Commission on Radiation Protection and the World Health Organization. At national level the National Committee on Radiation Protection, which has great stature as a result of the eminence of its individual members, operates actively. Although there is now no direct connection between it and the National Bureau of Standards, the latter makes it a practice to issue recommendations of the Committee in handbook form.

Waste Control Measures

Atomic industry waste control presents special problems. Scientists in the atomic field generally agree that, because of the techniques now available, an atomic energy installation may be located in a densely populated area without creating a public health or safety problem as a result of atmospheric and stream discharges. The methods used would not be the same in every case and would vary somewhat with location. Some of the available waste control methods are still in the developmental stage and have not as yet been finally crystallized.

Before describing the waste control techniques which are peculiar to the atomic energy industry it will be helpful to consider some of the broader aspects of waste control, including practices which appear to have considerable future potential as a result of their use in certain locations. In an atomic age, these practices will assume an even greater importance.

Waste Reduction Through Water Conservation

The first step to take in solving a waste problem is, obviously, to reduce

the amount of waste. Water conservation is vital, not only in the reduction of industrial waste but also in the interest of protecting the nation's water supply. There is an increasing shortage of water in various parts of the country and this is an added, and most important, reason for conserving the use of water in industry.

While the national water table is gradually dropping, the nation's municipal and industrial water requirements are increasing at a tremendous rate. Consumption for these purposes for 1955 is listed at 78 billion gallons per day. It is estimated that the demand in 1975 may be as high as 145 billion gallons per day.

A considerable portion of the water consumed by industry is discharged as waste. Sound usage of water will reduce not only the volume of waste but also the size of the treatment plants required. There is a growing recognition in industry of the importance of controlling water usage for the dual purpose of reducing waste (for economic reasons) and of conserving the nation's most valuable natural resource. More and more companies and plants are organizing water-management programs and assigning personnel to the water and waste control field. At General Electric's Appliance Park in Louisville, Ky., spray ponds and a pump house permit large quantities of water to be used over again.

Effluent Re-Use

Treated sanitary and industrial effluents represent a large supplemental source of water supply for process purposes in industry. The extensive re-use of such effluents would greatly reduce the volume of wastes being discharged into the streams of the nation.

There are not many plants so far which are putting this method into practice. One outstanding example, however, is the Bethlehem Steel Company's Sparrows Point Plant which uses treated sewage from Baltimore, Md. The agreement to use the city effluent for this purpose was made in 1941. The company provided a treatment plant after studying in detail the quality of the effluent. The treatment plant consists of coagulant feeders, flash mixer, flocculators, mechanically cleaned settling basins, fine screens and chlorinators. The main function of the treatment plant is to reduce the suspended solids content of the effluent. Figure 1 shows the settling tanks and chlorine contact facilities at The Bethlehem Steel Company's plant for chemical treatment and chlorination of Baltimore sewage effluent.

In 1954 Bethlehem Steel used an average of 59.6 million gallons of effluent a day, for which it paid $40,589. The practice has been beneficial both to Bethlehem Steel and to the City of Baltimore. It provided the industry with a source of water when the chloride content of its wells became too high. The city profited because its pollution load to the stream was greatly reduced and there was a corresponding reduction in the chlorination cost of the effluent.

Industries and municipalities of all sizes must install waste treatment facilities if they are to do their part in protecting the nation's water resources. Serious thought, therefore, should be given to the soundest and most economical means of providing such treatment.

One possible solution is for the industry and the city individually to provide equipment which will deliver a satisfactory effluent. In the case of many large industrial installations, this seems to be the best answer. In other cases the soundest approach appears to be for the city and its industries to do the treatment job in a single plant. In such cases it might sometimes be necessary for the industries to provide pretreatment facilities also so that the city treatment plant could handle the wastes satisfactorily. A number of cities are already using this approach. However, considering the magnitude of the pollution control

FIGURE 1.—Settling tanks and chlorine contact facilities used to treat Baltimore, Md., sewage effluent for industrial use.

job, it is obvious that more municipalities and industries should give thought to solving the problem by such joint action.

An interesting expansion of the combined city-industry solution to the pollution control problem is the organization of the system on an area-wide basis. It is often less expensive for two or more municipalities in an area to develop a common sewer system and sewage treatment plant than for each one to solve the problem alone. Where this situation exists, the industries in and adjacent to each city should consider the possibility of combined fa-

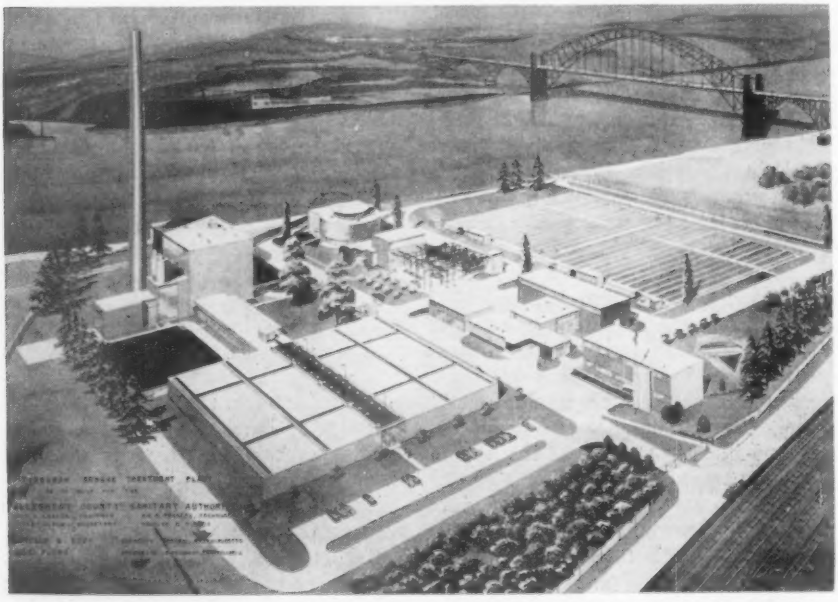

FIGURE 2.—Architects sketch of sewage treatment plant under construction for the Allegheny County Sanitary Authority, Pittsburgh, Pa.

cilities for the treatment of their waste. Industries located at a distance from the city can be connected to the system independently.

The most notable example of this type of operation is the collection system and treatment plant for the Allegheny County Sanitary Authority in Pittsburgh, Pa. Begun in February, 1956, this $100 million project is scheduled to be completed in three years. Sixty-eight municipalities and 20 industries are jointly solving their waste problems through this mammoth system. When the industries which are tied into the various municipal systems are added to the 20 which deal directly with the Authority, well over 100 plants will be parties to the project. An architect's sketch of the plant for the Authority is shown in Figure 2. It will handle a flow of 150 m.g.d.

Utilization of Sludge

Sludge is a by-product of sewage treatment which has always been difficult to dispose of. Many authorities feel that this sludge should be returned to the land to replenish certain trace elements which, in spite of the use of chemical fertilizer, are removed from the soil by the continuous growing of crops. A number of sewage treatment plants in the country have been successful in disposing of sludge for the turf-building and fertilizer value which it may have. Milwaukee has done an outstanding job of selling sewage sludge for fertilizer. Milorganite, a dry, sterile, sewage sludge, has been on the market for about 30 years. Figure 3 shows the Milwaukee sewage treatment plant where Milorganite is produced. Other cities are following the same practice but their products are not yet as well known. Schenectady, N. Y., for instance, produces Orgrow, also a pulverized sterile sludge.

Another way of making use of sewage sludge is now being developed. The Milwaukee Sewerage Commission and the Vern E. Alden Company, a Chicago engineering firm, have a plant under construction to make Vitamin B-12 from sewage sludge. Armour Laboratories will receive the aqueous concentrate from the plant and carry out final processing. Stock feed-grade material will be the first product of this new venture.

Atomic Waste

The ways and means of handling wastes which have been discussed can, in varying degrees, aid in solving the

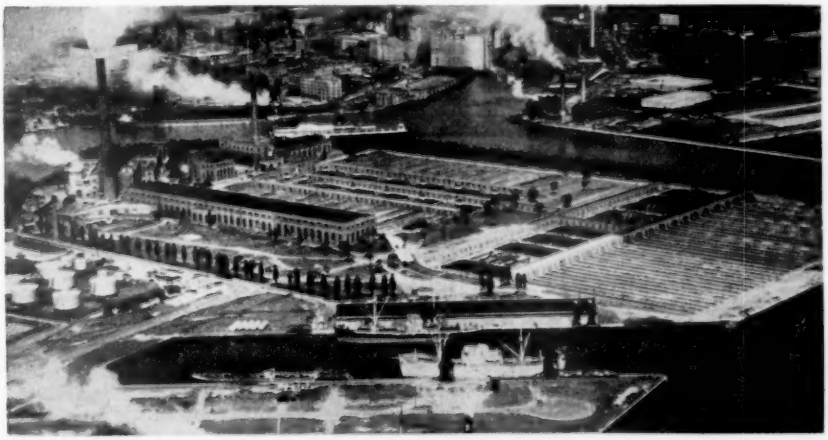

FIGURE 3.—Milwaukee sewage treatment plant.

problems of atomic waste disposal. But specialized techniques obviously must be developed in order to prevent widely distributed atomic energy installations from creating stream pollution problems. The following are some of the most promising approaches:

1. The recovery of by-product isotopes from plant wastes. This method has been under study for some time.

2. The use of ion exchange resins in the treatment of waste water from atomic energy plants. This may permit de-activation of large quantities of highly-treated cooling water which can then be re-used.

3. The concentration of radioactive wastes so that large quantities of radioactivity can be contained in a small volume of material. This concentration will make possible the removal of the objectionable radioactivity from the plant site. Such concentration may also increase the possibility, in some cases, of recovery and re-use of isotopes.

4. The use of biological treatment for the reduction of radioactivity in waste waters.

5. Investigations of the techniques and potentialities for deep-sea disposal of concentrated radioactive wastes.

6. Investigation of techniques for making full use of the ion exchange capacity of selective and currently unused subsurface strata to absorb radioactivity.

7. Studies of the methods and techniques of confining and immobilizing waste materials with radioactive properties to limit the degree and extent of the contamination of soil or water in which the waste has been deposited.

8. The development of extremely accurate monitoring and recording devices to detect the slightest malfunctioning of atomic energy equipment. At the first indication of trouble the plant can promptly be shut down.

Conclusions

The subject of waste treatment in the atomic age is too broad to cover in a single paper. Since this is the case, an effort has been made in this presentation to touch briefly upon some of the outstanding waste control developments which it is felt will have greater application in this eventful era. The development of such techniques for the proper control of atomic wastes is a part of a vast expansion of nuclear technology which is a mark of the times.

Progress in the field of industrial waste control is inevitable as atomic energy develops into a major industry in America. Since this is true, it is hoped that this summary will tend to help stimulate thought on the part of the personnel in this field as to the techniques which may have the greatest potential in achieving such progress.

30TH ANNUAL MEETING

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FEDERATION OF
SEWAGE AND INDUSTRIAL WASTES
ASSOCIATIONS

HOTEL STATLER

BOSTON, MASSACHUSETTS

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CLARIFICATION OF DREDGE MINING WASTE WATERS *

I. CLARIFICATION TESTS

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Much of Idaho's gold and rare-earth mineral wealth lies in the sedimentary deposits in the high valleys and canyons of the state. These areas are generally sparsely populated and the chemical quality of the water in the streams is excellent. Recovery of these precious and vital minerals is undertaken by dredge operations, usually with floating dredges. The operation involves excavation of the soil to depths of up to 50 ft. Separation of the minerals from sand, rock, and other undesirable material is accomplished in water by the difference in specific gravity between the desired material and the undesirable materials.

In all of the known operations in Idaho, clay-like material has been excavated along with the sand, rock, and gravel and, in the washing and settling operations, this clay becomes colloidally suspended in the water. For the most efficient separation of the mineral from the waste material, a liquid media with a low specific gravity is desired and, unfortunately, the accumulation of clay in the water increases its specific gravity. Therefore, fresh water is constantly added to the dredge pond, and waste water, containing the colloidally-suspended clay, flows out of the ponds.

In conjunction with several of the dredging companies in Idaho, the Idaho State Mine Inspector and the engineers of the Idaho State Land Department requested the advice and assistance of the Idaho State Board of Health in solving the problem of clarifying this waste water. The results of some of the clarification tests which were conducted by the Board of Health and some of the full-scale experiences in clarification at the Idaho-Canadian Dredging Company operations near Cascade, Ida. will be dealt with in this paper. The results of a waste water clarification research project which was conducted at the University of Idaho will also be reported.

Characteristics of Dredge Mining Wastes

Source of water for the dredging operations in the Cascade area is Big Creek, a tributary of the North Fork of the Payette River. This water is clear, has a pH of about 7.0, and contains less than 100 p.p.m. total solids. In several analyses of the waste water from dredge ponds it was found that the pH of the water was not changed materially and that the total solids ranged from 9,800 to 19,900 p.p.m. This colloidal material imparted a brown color to the waste water.

Waste flow from the dredge pond was never measured but it was estimated at approximately 1 m.g.d. Operation of the dredges was continuous and at a constant rate. Attempts to remove the suspended matter by sim-

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ple sedimentation in relatively large ponds, which provided several days of detention time, were completely unsuccessful; total solids in the effluent were equal to total solids in the influent.

Results of Clarification Tests

Inorganic Polyelectrolytes

Coagulation-sedimentation tests, made in a manner similar to that used in jar tests in a water filtration plant, were conducted on a sample of water from the dredge pond of the Idaho-Canadian Dredging Company near Cascade early in 1952. This sample was taken while the dredge was not in operation and the concentration of solids was somewhat greater than that which was later found in dredge-pond waste water during normal operations. It was felt, however, that the results of these tests were indicative of the results which could be expected with normal dredge waste water. The tests revealed that lime, alum, sulfuric acid, iron salts, and combinations of lime and alum or iron salts, could be used for the clarification of the dredge-pond water. Minimum doses of coagulants required for complete clarification are shown in Table I. All chemicals used in tests by the Idaho State Board of Health were applied as aqueous solutions to the waste water.

TABLE I.—Minimum Doses of Coagulants Required for Complete Clarification of Dredge-Pond Water

Coagulant	Dose (p.p.m.)
Hydrated lime	680 as $Ca(OH)_2$
Alum and hydrated lime	170 as $Al_2(SO_4)_3 \cdot 16 H_2O$; 90 as $Ca(OH)_2$
Sulfuric acid	850 as H_2SO_4

From these tests it was concluded that the combination of lime and alum might be the most economically satisfactory method for treatment and that further study was indicated.

In August, 1952 the dredging company endeavored to treat its wastes by applying a relatively low dose of hydrated lime with a small homemade feeder. Average dosage was estimated as 25 p.p.m. of $Ca(OH)_2$. Tests on the raw waste and the treated effluent from a settling pond showed that no reduction in total solids was being effected. Samples of the dredge-pond wastes were taken and coagulation tests were made to determine the optimum dosage of lime. The waste sample contained 13,700 p.p.m. total solids and it was found that 135 to 170 p.p.m. of calcium hydroxide would give excellent clarification. Lower doses of lime gave partial clarification. Tests on sample portions, which were kept at 40° F., gave the same results as the other tests in which sample temperatures were 70° F. or over.

In conducting these tests it was found that the use of graduate cylinders with a short period of agitation gave identical results as the use of jars with a longer period of slow mixing. All remaining tests were made with graduate cylinders. The floc, which was formed by the application of lime, was light and settled slowly. About 12 hr. of settling was required to obtain a sludge volume equal to 35 per cent of the original water volume. It was observed that the settling rate of the floc varied in subsequent tests, although it was always slow. The floc could be easily resuspended by disturbance of the settled sludge. This indicated the need for relatively long detention periods and possibly for some method for the removal of the settled sludge from the ponds. On the basis of these observations it was suggested that the dredging company should consider the possibility of obtaining quick lime for use as a coagulant.

Hydrated Lime and Gypsum

It also was suggested that consideration should be given to the use of

waste hydrated lime from the Linde Air Products Company acetylene plant at Boise, Ida. This waste material is discharged as a slurry to a drying pond. The amount of waste lime from this plant was believed to be adequate to supply the requirements of the dredges. Coagulation tests were made using this dried material and it was found that results were comparable to clarification with reagent grade hydrated lime. Analyses of waste-lime samples indicated a variable amount of moisture, generally not less than 60 per cent.

On one occasion a dose of several thousand parts per million of this waste lime was applied directly to the dredge pond. Clarification of the water at the surface of the pond was apparent but movement of the dredge and buckets prevented adequate settling of the sludge. Although this material was shown to be a satisfactory coagulant, its use was discontinued because hauling costs were high and difficulty was experienced in handling this moist, lumpy material.

Clarification tests also were made using gypsum from fertilizer plants as a source of calcium. This is a by-product which has limited use as a low grade fertilizer and/or soil conditioner. A sample of this gypsum which was dry and powdery and easy to handle was used in coagulation tests. At dosages of 300 p.p.m. this material gave comparable results to 200 p.p.m. of laboratory reagent-grade calcium sulfate. The sample which was treated contained 19,900 p.p.m. total solids. Because of high hauling costs, however, this material was never used at a dredging operation.

During the summer of 1954 the Idaho-Canadian Dredging Company and Baumhoff-Marshall Dredging Company at Cascade used reject burnt lime from a beet sugar refinery for the clarification of their wastes. This operation was highly successful. About 2 m.g.d. of waste were dosed with lime, mixed in a rapid mixer, and discharged to a large settling pond more than 10 acres in area. Results were excellent. Sludge accumulated in this settling pond until it started to overflow with the effluent. At that time a pump was inserted in the pond and sludge was periodically pumped from this pond into a smaller sludge-drying pond. Dosage was not closely controlled and was not precisely known, but the lime feed was adjusted to maintain a clear efflu-

Organic Coagulants

In April, 1955, at the request of the superintendent of the Idaho-Canadian Dredging Company, coagulation-sedimentation tests were made on a sample of waste using an organic coagulant * and hydrated lime. It was desired to compare the efficiency of the organic coagulant with that of lime and to determine if it could be economically used as a coagulant or a coagulant aid. Total solids analysis in the dredge waste sample was 9,800 p.p.m.

An aqueous solution of the organic coagulant was used as suggested by the manufacturer. These tests revealed that the organic coagulant alone was about equal in effectiveness to lime alone; about 200 p.p.m. of either lime or organic coagulant were required to clarify the waste sample. A test in which 100 p.p.m. of lime and 0.5 p.p.m. organic coagulant were used together indicated that some benefit may be obtained by use of the combination of these two materials. Price quotations of the two materials at the time were in the ratio of about 90 to 1, so it appeared that the organic coagulant might not be economical.

There was a great difference in the size and density of the coagulated floc material formed by the lime and that formed by the organic coagulant. The floc formed by the addition of lime was slow settling and voluminous. The floc created by the organic co-

* Separan 2610, Dow Chemical Company.

agulant was a relatively large sponge-like particle of irregular shape which settled to a compact mass in a short period of time. Two hours were required for the lime floc to compact as much as the organic coagulant floc had in 5 min. It is possible that the organic coagulant, or other similar products used, might have application where space for settling ponds might be unavailable or available only at premium prices, or where it is desired to minimize the detention time. Further study is indicated.

University of Idaho Tests

In a report on the precipitation of colloids from irrigation waters, Cone and Thompson at the University of Idaho concluded, as a result of coagulation tests on a sample of waste dredge water from Cascade, that alum, lime, calcium chloride, magnesium salts, and probably other polyvalent electrolytes, could be used for clarification. Alum was recommended as a coagulant because, in comparison with lime, only one-half as much of this material was required for clarification. Even though the cost of alum treatment was slightly higher, alum was recommended because of the greater simplicity of handling the smaller quantities. It was indicated, however, that the other materials (such as lime) might be found preferable in some cases. A trial use of coagulant, applied directly to the dredge pond, was suggested.

An approximate cost of clarification by electrophoresis was also determined. A sample of the dredge pond wastes was completely clarified by the application of an electric potential and passage of a small current through the sample in a laboratory unit. Cost of this method was shown to be excessive and it was anticipated that there would also be mechanical problems in designing facilities for the removal of the sludge and prevention of fouling of the electrodes which would further increase the cost and complicate the method.

Characteristics of Clarified Effluent

The pH of clear effluents obtained by the application of hydrated lime varied from 9.0 to 10.5. One effluent analysis showed a pH of 10.1, total solids of 250 p.p.m., and a hardness of 56 p.p.m. as $CaCO_3$.

Residual quantities of the coagulants in the effluent and the effects on water quality for downstream usage were not investigated. The quantity of aluminum or iron salts in the effluent was expected to be small. The increase in calcium content when calcium salts were used as coagulants was not significant.

The amounts and type of impurities in the waste lime from the acetylene plant are not known but no material which would be detrimental to aquatic life or other legitimate water uses was expected. The waste gypsum from phosphate fertilizer plants contains some phosphoric acid, or other soluble phosphate and some fluoride. When used in the suggested dosages, it was anticipated that the quantities of these materials would be insufficient to be harmful to water quality. Small amounts of phosphate might stimulate algae growths in a settling pond or in a receiving stream and this possible effect should probably be investigated. No information was obtained on the characteristics of the organic coagulants as regards effects on water quality and the various water uses. At Cascade, flow in the receiving stream was at least 10 times the waste flow. This dilution may be adequate to prevent stream degradation by residuals of the coagulants or their impurities.

Conclusions

Water-borne dredge-pond wastes consist of stably suspended colloidal material (brown clay), which cannot be clarified by simple sedimentation. The Idaho State Board of Health con-

ducted limited preliminary coagulation-sedimentation tests on dredge-pond waste water samples. These wastes can be completely clarified by coagulation with the usual water filtration plant coagulants, such as alum and iron salts, or by calcium salts, other polyvalent electrolytes, or sulfuric acid followed by sedimentation. Industrial wastes which contain calcium, such as waste-hydrated lime from acetylene plants and waste gypsum from phosphate fertilizer plants, also can be used as coagulants. These results were confirmed by similar tests at the University of Idaho.

The University of Idaho investigation also revealed that the wastes could be clarified in laboratory equipment by electrophoresis. This method is much more expensive, however, than clarification by chemical coagulants and would require the design of equipment for full-scale operations.

Organic coagulants, such as Separan 2610, were found to give satisfactory results and a fast-settling floc, but the cost appeared to be considerably greater than that required for conventional coagulants. It is conceivable, however, that these organic coagulants may be justified in unusual situations. Lime was used successfully as a coagulant by two dredging companies.

II. TREATMENT OF WASTE WATERS AT BEAR VALLEY, IDAHO

By Robert P. Porter

President, Porter Bros. Corporation, Boise, Idaho

The method of treating dredge-mining waste waters can vary greatly due to the composition of the gravels being dredged, the yardage output per day, and the volume and characteristics of the water in the stream or streams involved. The purpose of this paper is to explain the method of treatment employed and the results obtained by Porter Bros. Corporation at their dredging operation in Bear Valley located in Valley County, one hundred miles northeast of Boise, Idaho.

Operation

The company is operating two bucket-line dredges. One dredge has a 4¼-cu. ft. bucket capacity and the other has a 6-cu. ft. bucket capacity. The dredges operate 24 hr. a day, seven days a week, nine months per year, handling 7,000 cu. yd. of material per day. The material dredged is gravel and clay which is washed and concentrated for the purpose of recovering euxenite, a rare metal-bearing crystal which occurs in the gravel beds.

The first step in the operation is the by-passing of all of the water from the main stream and tributaries which is not required for the dredge pond, or ponds. In Bear Valley, the main flow of the creek is carried around the dredging operations by means of a diversion dam and two ditches or canals which discharge into the original stream bed below the working area.

The make-up water required for the dredge ponds is obtained from a small tributary of the main creek and may also be obtained from the main stream by means of a weir which is closely regulated so that only the necessary amount of water for washing the dredged material is taken from the streams. The water required for the 4¼-cu. ft. dredge is 500 to 600 g.p.m. and for the 6-cu. ft. dredge it is 800 to 1,000 g.p.m. This governs the amount of water to be treated.

At the beginning of an operation an initial settling pond is constructed and, as work progresses, the dredges construct their own settling ponds be-

tween rows of tailings that are formed behind the dredges. At Bear Valley the initial settling pond covers an area of approximately five acres and, since operations have been proceeding, additional settling ponds are being completed faster than the older ponds are being filled with slimes. The shape and position of the ponds depends on the contour of the ground and the plan of dredging followed in the particular area.

The waste water discharged from the dredge ponds is accumulated by ditches and run to a common sump. From there it is pumped to a building which houses a reagent mixer and the reagent feeders which add the coagulant. It is mixed by passing it through a sluice box and then discharging it into the ponds to settle in order to effect the desired clarification.

The water is passed into the initial settling pond where the first settling takes place. The clearer water from this first settling pond is partly filtered through the walls of the pond and partly decanted from the surface of the pond. This treatment does not remove the finer particles and colloids. These are removed in a second pond where additional detention time is provided. The water from the second pond flows through a restricted weir and is returned to the original stream.

The water in the dredge pond is light brown in color with a turbidity of 55,000 p.p.m. and a total solids content of 44,000 p.p.m. In the second settling pond the water has 200 p.p.m. of solids and, when discharged into the stream and mixed with the stream water, the suspended solids are less than 25 p.p.m. This represents a reduction of over 99.9 per cent in both values. The pH is 6.5 in the first settling pond, 7.0 in the second pond, and 8.0 or higher in the stream after the discharged water is mixed with stream water.

If the original settling pond becomes filled with floc, and thus is not active, another pond may be used or the situation may be relieved by employing an additional pump to pump the heavy floc to another location or put it on top of the existing tailings.

Selection of a Coagulant

In selecting a coagulant for treating dredge-mining waste waters, it is very desirable to run tests on each location and for each condition. At Bear Valley, after many experiments with various combinations of coagulants, it was determined that a combination of sulfuric acid and an organic coagulant * was most effective, but the same results may or may not be duplicated by the same means in other localities. At Bear Valley alum and lime produced a good floc but required a heavy dosage of alum and had the further disadvantage that all of the floc would not settle. Ferrous sulfate and lime were slow in settling, even at large dosages. The organic coagulant and alum produced rapid floc formation but all floc would not settle and leave a suitable supernatant. This coagulant and sulfuric acid produced the best results at all temperatures of the water.

Quantities Required

The amount of sulfuric acid required was 0.011 gal. per thousand gallons of water, and the amount of organic coagulant required was 0.0013 lb. per thousand gallons of water. Adding additional coagulant did not appreciably increase the settling, but increasing or decreasing the amount of sulfuric acid did permit control in order to achieve the desired effect.

Addition of Coagulant

The acid was added in concentrated form with a stainless steel reagent feeder. The dry organic coagulant was mixed with water by agitation in a mixing tank to produce a 1 per cent solution. The reagent feeders were operated automatically by the electri-

* Aerofloc 548.

cal system controlling the pumping system which handled the dredge water. When the water pumps start, the feeders immediately start adding the coagulants.

Costs

The cost of these coagulants is approximately $0.01 per thousand gallons of water for the sulfuric acid and $0.001 per thousand gallons of water for the organic coagulant. The average number of gallons treated per minute is 1,800.

The cost of the coagulants is by no means the entire cost in treatment of dredge waste waters. It is necessary to maintain pumps in operation and have pumps available on a standby basis at all times in order that the treatment plant may be capable of operation whenever required. Additional pumps must be provided to relieve the settling ponds of excess floc which is disposed of by pumping it on top of tailings. It is necessary to have a man on duty at all times to check the pumps and reagent feeder. Additional equipment must also be provided for the construction of ditches and for changing the flow of water from one pond to another as required.

Conclusion

The method employed by Porter Bros. Corporation in treating the dredge waste water at Bear Valley, Idaho, is the most effective so far developed for this particular operation.

PROCEEDINGS OF THE 1957 NUCLEAR CONGRESS

The Proceedings of the 1957 Nuclear Congress will be available August 15 from the American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y. Publication price will be $45.00.

The proceedings will be published in three volumes, with the papers and discussions from the Second Nuclear Engineering and Science Conference in two of them, and those presented at the 5th Hot Laboratories and Equipment Conference in the third.

Also available at $28.00 (a saving of $8.00) are the two volumes containing selected papers from the First Nuclear Congress.

The rich fund of information brought into both the 1956 and 1957 Nuclear Congresses will open new avenues for the peaceful use of atomic development. The Federation was one of the sponsors of the 1957 Congress.

MODIFIED LABORATORY TURBIDIMETER FOR FIELD USE ON MINING WASTES

By C. A. Johannes and R. D. Miller

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The need for a portable instrument capable of measuring the turbidity of mining waste samples in the field has probably been experienced by many people in the field of industrial waste control. Portable equipment which makes it possible to obtain a quick and on-the-spot determination may often be of importance from a control standpoint. Accuracy may also be improved, since indications are that some samples do change in turbidity over a period of time. On-the-spot determinations of turbidity, if sufficiently accurate and reliable, may also save time because they preclude the necessity for special packing and transporting of samples to a distant laboratory for analysis.

This discussion is concerned with modification of a standard laboratory Hellige turbidimeter to utilize a 6-v. power source, its installation in an automobile, its calibration, and the operational results obtained.

Modifications

A wooden base, 11 in. by 14 in. and ¾ in. thick, was provided to give the instrument stability for use in an automobile, and to provide a surface for attachment of the voltage controls. The 110-v. bulb furnished with the instrument was replaced with a 6-v., 75-w. standard base bulb, and the turbidimeter was rewired for 6 v.

Because the effect of voltage variations on the turbidity determination was not known, it was considered desirable to provide a means for controlling the voltage and thereby controlling the intensity of the light reaching the sample tube. A fixed resistance of ½ ohm with a 25-ohm variable resistance in parallel was, therefore, included in the turbidimeter circuit and mounted on the wooden base. Addition of a D.C. voltmeter with a range of 0 to 15 v. and a D.C. plug fastened to the instrument leads completed the modification.

Installation

The instrument was mounted in such a manner that it could be easily and quickly removed and the automobile used for other purposes. A table 11 in. by 14 in. and 20 in. high was constructed to rest on the floor of the automobile behind the front seat for the purpose of supporting the instrument (Figure 1). This location permitted the operator to sit in the back seat of the car while making the

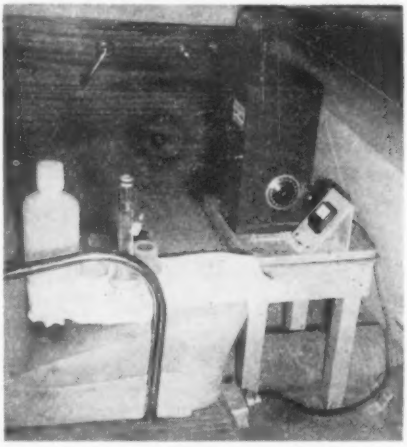

FIGURE 1.—Laboratory turbidimeter mounted for field use.

determinations. When the turbidimeter was not in use, it could be placed on the back seat in a case if desired.

A connector to receive the D.C. plug of the instrument was fastened to the side of the car in a convenient location and was wired to the automobile starter terminal with a heavy rubber coated electrical cable.

Calibration

After a few preliminary tests, it was decided to standardize operation of the instrument at 5½ v., using a 20-mm. sample tube and a dark filter. It was found on trial that 5½ v. could usually be obtained from the standard automobile storage battery for the short period of time required for a determination without excessive drawdown of the battery and without the necessity of simultaneously charging the battery by means of the automobile generator.

Calibration of the instrument was accomplished by placing samples of known turbidity in the instrument and, after proper adjustment of the inner and outer fields, noting the shutter dial readings. Distilled water was used as one sample representing a turbidity of 0.0 p.p.m. and several other samples were prepared ranging from 1 to 90 p.p.m. turbidity. The samples were made from a standard Hellige silica suspension by dilution with distilled water. Three readings were taken on each sample of known turbidity and the average reading was plotted against the known turbidity of the sample (Table I).

TABLE I.—Calibration Data for Modified Turbidimeter

Turbidity of Standard Sample (p.p.m.)	Scale Reading		
	Max.	Min.	Avg.
0	5	5	5
4	8	8	8
10	13	12	12.7
15	17	17	17
20	24	23	23.3
30	31	30	30.3
40	40	38	39.0
50	49	47	47.7
70	57	56	56.3
90	75	70	72.7

The lower strength samples can apparently be read with less absolute error, although the percentage error, or lack of precision, may be higher than is the case with the higher strength samples. The increase in absolute error in reading the higher strength samples is thought to be

TABLE II.—Effect of Voltage Variation on Turbidity Reading

Instrument Voltage	Range	Turbidimeter Scale Reading					
		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
5.5	Max.	14	25	35	48	61	66
	Min.	12	24	30	45	57	60
	Avg.	13.0	24.3	32.0	46.7	59.0	63.7
5.0	Max.	14	27	37	50	61	77
	Min.	12	23	32	45	55	66
	Avg.	12.7	25.0	34.3	47.3	58.0	71.0
4.5	Max.	15	27	35	48	56	80
	Min.	14	23	29	45	53	75
	Avg.	14.7	24.3	32.7	46.7	54.3	78.3
4.0	Max.	13	26	30	51	56	88
	Min.	12	24	24	49	54	70
	Avg.	12.3	25.0	26.7	50.3	55.0	76.0

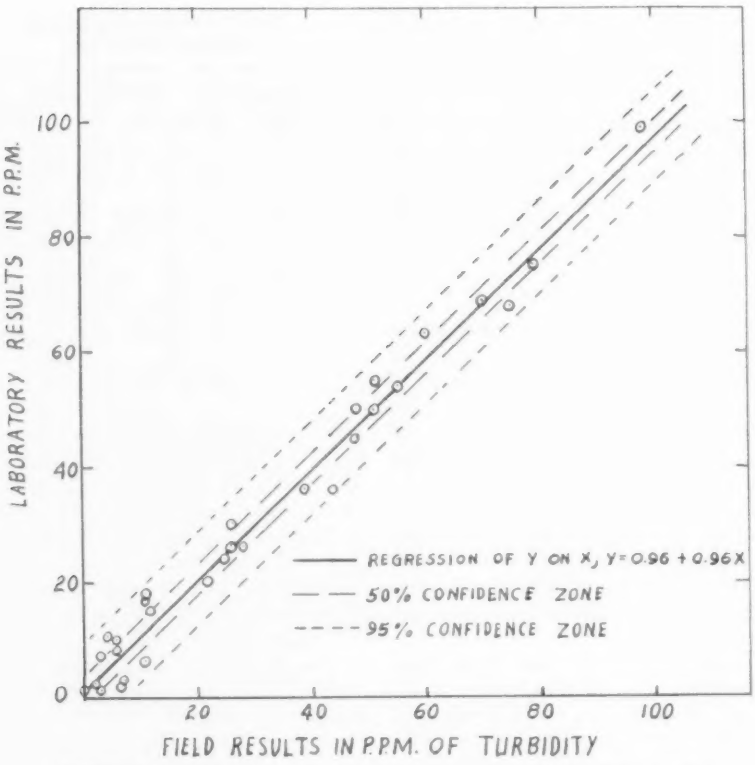

FIGURE 2.—Comparison of field and laboratory turbidimeter results.

caused mainly by increased scatter of light by the particles of the suspension, with a resulting loss in the ability of the viewer to differentiate between scattered and transmitted light, *i.e.*, the high intensity of the light makes it more difficult to compare the fields. When the turbidity of the sample is much greater than about 100 p.p.m., the scattering and absorption effect usually becomes so pronounced that a direct determination cannot be made. When this occurs, a known volume of the sample is diluted with a known volume of distilled water, the turbidity of the diluted sample is determined in the usual manner and this result is then multiplied by the dilution ratio to obtain the turbidity value of the original sample.

A series of determinations was made at different voltage levels to determine the effect, if any, of a decrease in voltage. Six different samples were prepared and read at lower voltage levels. The results are given in Table II.

The differences found in reading the samples at the lower voltage levels were not considered significant in that a trend toward poorer results was not definitely established. The use of lower voltages is not considered desirable, however, because of the likelihood that the resulting lower light intensities might accentuate the problem of differentiating between transmitted light and scattered light at the extreme upper turbidity ranges, thus, in effect, limiting the range of the instrument.

Results

Thirty-one turbidity determinations of treated and untreated iron ore mining wastes were made in the field and duplicate determinations were made in the laboratory on the shipped samples.

Analysis of the data revealed a high degree of correlation between the field method of turbidity determination and the laboratory method; the correlation coefficient was found to be 0.99. A regression line was calculated on the assumption of straight-line variation and was found to fit the equation $y = 0.96 + 0.96\ x$ where y is the laboratory result in parts per million and x is the field result in parts per million (Figure 2.)

The 50 per cent confidence limit of ± 2.9 and the 95 per cent confidence limit of ± 8.4 are as shown on the graph and indicate the degree of confidence in the probability that the value of y corresponding to a given value of x will be found within the specified limits. The regression line itself indicates the most probable value of y for a given value of x. The standard deviation of the differences between the field and laboratory results was found to be 2.1, from which it was calculated that the probability of occurrence by chance of a difference as great as 5 p.p.m. or more is only about 1 in 5 and, similarly, a difference as great as 10 p.p.m. or more may be expected to occur by chance alone only once in about 1,700 determinations.

Summary

A relatively inexpensive and sturdy modification of a laboratory turbidimeter has been developed to enable the investigator to make a rapid and reliable on-the-spot determination of turbidity in the field. The instrument can be readily transported in an automobile. The power source is an ordinary 6-v. storage battery.

The instrument was calibrated by means of the standard turbidity suspension for the particular type of instrument. Operation was standardized at the convenient level of 5½ v.

Some 30 samples of iron ore mining wastes were analyzed in the field and later in the laboratory for comparison purposes. The results of an analysis of the data indicate a high degree of correlation between the analytical results obtained by the field method and the laboratory method.

Acknowledgment

The assistance of R. E. Frazier, Chief, Engineering Laboratories, Minnesota Department of Health, is sincerely appreciated.

TEXTILE WASTES—RECOVERY AND TREATMENT*

By R. H. Souther and T. A. Alspaugh

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The modern textile industry, like many other industries today, recognizes the importance of the proper use of water. This means having a good supply of pure water, using it, and then returning it to the receiving stream in good condition for others to use in turn. The tremendous increase of new industries throughout the nation, particularly in the South, has presented an ever-increasing problem in the minds of industrial planners as to water supply and waste disposal. These two factors are just as important in selecting a site for a new industrial plant as the source of labor or transportation facilities. Therefore, a proper function of the textile research laboratory is research in waste reduction and waste disposal problems.

A great deal of work has been done on the treatment of different types of textile wastes (1). Some of the treatment methods evolved include neutralization, coagulation and precipitation, equalization, and both chemical and biological oxidation. Although there is no tailor-made solution that fits every textile waste problem, if cheap simplified methods could be worked out to reduce the alkalinity of textile wastes, the problem would be closer to a solution. It is a proven fact that a neutralized waste, containing no toxic substances, is more easily adapted to biological treatment. A method that shows promise in this direction is neutralization of textile wastes with carbon dioxide recovered from power plant stack gases (2).

* Presented at the 1956 Annual Meeting, Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.; Chattanooga, Tenn.; Sept. 17–19, 1956.

This paper discusses some of the ways and means used to reduce the liquid waste load from textile mills. The methods discussed include closer control of wet processes, process modification, recovery of usable products for re-use, substitution of low-B.O.D. chemicals for higher B.O.D. ones, and good housekeeping practices. Also discussed are the various means of treating textile wastes. These include physical, chemical, and biological methods.

A question that comes up many times is covered from the textile angle. This question is: "Does combined treatment of industrial wastes and sewage give more efficient and more economical results than treatment of industrial wastes and domestic sewage separately?" The pilot plant data necessary for this discussion were obtained on a typical textile wastes mixture. Some of the data on combined treatment are quoted from two other papers on that subject by the authors. The pilot-plant data on separate treatment were obtained especially for this discussion.

Historical Background

Some of the outstanding research on textile waste treatment was carried out by the Textile Foundation in the late 1920's. This work has not been surpassed in its basic concept for treating textile wastes, although the work did not go far enough in the investigation of the treatment of highly alkaline textile waste without pH adjustment.

This work was jointly sponsored by the North Carolina State Board of Health, the City of Greensboro, and

Cone Mills Corporation and was carried out at the Cone Print Works plant (3). Miles and Porges (4) demonstrated on a pilot-plant scale that successful treatment of a sulfur dye-sewage wastes mixture by the activated sludge process was practical on mixtures containing up to 3 per cent of the concentrated sulfur dye waste. It was concluded that both the activated sludge process and biological filters employing recirculation of the effluent could be used to treat textile wastes–domestic sewage mixtures. The activated sludge process removed color better than did the biological filters, but was more easily upset by variations in the wastes (5). Other investigations were carried out to determine the coagulants best adapted for precipitation of textile wastes, methods of applying these chemicals, the best pH range for coagulation, and any correlation between pH zone and the coagulant used (6). The origin of the studies at Cone Mills lies in the biological treatment of highly alkaline textile mill waste-sewage mixtures with and without chemical pretreatment.

Reduction of Waste Load

Process Control

The first step in the study of any industrial waste problem is to see if closer process control inside the plant itself can cut down on the total waste load. This involves studying the plant operations to see what processes have liquid wastes and how much is to be expected. Then the process itself is investigated to see if process modifications will cut down on the waste load (7).

Cone Mills Laboratory has spent considerable effort on this problem. The development of the Con-Mill method for measuring reduction potentional values for use in evaluation and control of dyeing and bleaching operation was a positive step in the right direction. This method for evaluation of indigo and vat dyeing operations was also adapted to sulfur dyeing. The amount of chemicals used for dyeing could be minimized and controlled closely by use of the redox potential and other modern methods of control. This closer control of chemicals used in dyeing operations cut down on the liquid wastes, but did not effect the quality of dyeing (8).

Another study made in cooperation with a dyestuff manufacturer showed that a change in the manufacture of the dyestuff itself would reduce the amount of sulfides in the spent dye liquor at the end of the dyeing cycle by 30 to 50 per cent. This would naturally lower the B.O.D. in the waste considerably.

Reduction in the volume of liquid dye waste from raw stock sulfur dyeing operations was realized by changing the method of dyeing. The usual method was to dump the dye bath after dyeing, and since only a certain amount of dye goes on the goods, the rest of the dye goes down the drain. Changes were made to the standing bath type of dyeing. In this setup, the dye liquor was not dumped, but was pumped to a tank and saved, and re-used in making up the next dye bath. This was a saving in the amount of dye necessary to make up a dye bath, and also a reduction in the amount of liquid waste because only the rinse water now entered.

A chief obstacle in treating textile waste is its highly alkaline nature. In the last 5 to 10 years a considerable amount of progress has been made in the recovery of waste caustic soda for re-use. Most textile plants try to re-use their caustic as many times as possible. But in some of the processes the caustic is either diluted to such a low concentration, or contaminated with impurities from cotton, water, dyestuffs, etc., that re-utilization is impractical and/or uneconomical from a quality standpoint. The great exceptions to this general rule are mercer-

izing, plisse printing, and, in certain cases, open boiling and certain other cotton purifying operations. The caustic soda distributed to these operations usually averages more than 80 per cent of total purchases.

In many bleacheries more than 70 per cent of the caustic soda which goes to waste could be recovered economically. The crux of the problem is efficient washing of the yarn or cloth. The residual caustic in the cotton must be at a low level to insure quality, and efficient washing removes the maximum amount of caustic with the minimum amount of water. Sometimes by efficient washing, the residual caustic content in the wash water is high enough for re-use without further treatment or expense. This is only true in a few cases, however.

In the majority of the bleacheries a considerable volume of caustic waste liquor remains, even after as much as possible has been re-used. If there is available annually an excess of 400 tons or more of actual sodium hydroxide at a strength of 2 per cent or more, then concentration by evaporation should be investigated.

The more the caustic is re-used, the more impurities it will contain; therefore, evaporation will further concentrate these organic and inorganic impurities. When the evaporated caustic is cooled, some of these impurities will go out of solution. This often is sufficient purification. But if the remaining soluble concentration of impurities is still high enough to affect the yarn or cloth quality, the caustic must be further purified by dialysis. The concentrated caustic is filtered through anthracite filters to remove any suspended insoluble impurities, then followed by dialysis to remove the soluble impurities. The dialyzed liquor at a concentration of 10 to 12 per cent is stored for re-use. It can be used as is or to dilute purchased caustic soda. It is expected that the return on the investment would be between 50 and 100 per cent, with less new caustic used and less caustic in the waste water (9).

Substitution

A fertile field that has been ignored until recent years is the area of investigation of substitution of low-B.O.D. chemicals for high B.O.D. ones. A study along this line has been made by the Rhode Island Section Subcommittee of the National Stream Sanitation Committee of the AATCC (10). This group has analyzed the B.O.D. of numerous chemicals commonly used by the textile industry. This should provide a guide for textile plants to use in the selection of low-B.O.D. chemicals.

Studies have also been made in the last several years on the substitution of carboxymethylcellulose (CMC) for starch, because starch is one of the major sources of pollution in textile finishing wastes.

The following shows the comparison between the B.O.D. of a number of finishing compounds (11):

Compound	B.O.D.* (p.p.m.)
Starch	477.0
CMC	9.0
Methylcellulose	1.6
Polystyrene (Stymer)	12.0
Polyvinyl alcohol (89½ hydrolysis)	16.0
British gum	690.0

* Based on 1,000-p.p.m. solution.

It can be seen that the B.O.D. of starch is high compared to CMC.

In a typical finishing plant approximately 52 per cent of the pollution load will be due to the desizing waste (starch). Of the products that can be substituted for starch, CMC seems to be the most promising, and when it is substituted for starch the B.O.D. is cut drastically but at a somewhat increased cost.

Another substitution that will cut the pollution load is the replacement of acetic acid with mineral acids in the

various dyeing processes. In a typical finishing plant acetic acid is responsible for 22 per cent of the total pollution load (11).

A field where substitution has made the most headlines is substitution of low-B.O.D. synthetic detergents for soaps and high-B.O.D. detergents. Some plants have cut their B.O.D. pollution load in half by this type of substitution. The alkylarylsulfonates are the best known of these low-B.O.D. detergents.

Housekeeping

One of the ways of reducing the pollution load from any manufacturing process is often overlooked—a day-to-day routine of good housekeeping. Good housekeeping practices do not usually make spectacular reductions in pollution loads, but in an area where every little bit counts they are indispensable. Close control of operations to avoid accidental spillage of dye baths, storage tanks, etc., saves money as well as avoids pollution. Making up too large a batch results in wastage when the excess cannot be used or stored and must be dumped to the drain. When spillage of toxic materials is unavoidable, a large volume of water should be used to wash down the area because the weaker the material, the easier the disposal.

Good housekeeping practices must be a cooperative effort between management, plant personnel, and the maintenance crews. This cooperation must include education to the benefits of the program, especially for the operating personnel, because a lot depends on them. The plant can be designed and engineered for minimum loss through breakage, spillage, splashing, etc., by construction of retaining walls, splashboards, sills and the like; but if the operating personnel do not cooperate, or know why certain things must be done certain ways, all the good design is lost.

Treatment of Textile Waste

The discussion on treatment of textile wastes is broken down into two sections: first, a general section on the three methods of treatment, and second, a section on specific examples of textile wastes and their treatment, including pilot-plant data. The discussion on whether separate or combined treatment of textile mill wastes and municipal sewage is cheaper and more efficient is included under the latter section.

Physical Treatment

The term "physical treatment" in this paper is taken to mean the practice of lagooning textile wastes. The purpose of lagooning is multiple. It serves to equalize flow as well as pollution load. It cools the temperature of the wastes and, depending on the storage time, type, and strength of the wastes, allows sedimentation of heavy particles, oxidation, and loss of B.O.D. and color—and on the debit side can cause obnoxious odors.

Depending on the wastes, lagooning can be a handy tool. Most of the time it serves only as a partial or pretreatment method and the effluent would have to overflow into a large waterway if lagooning were to be used as a satisfactory total treatment. There are cases, though, where lagooning has served as post-treatment after other treatment facilities, and in certain sections of the country it has returned to favor as a method of final treatment for domestic sewage (12). This practice is not looked on too favorably in the South at the present time either for municipal sewage treatment or combined municipal sewage and industrial wastes treatment. Lagooning or storage of wastes is now extensively used for industrial wastes treatment (separate from municipal systems) and as a pretreatment for industrial wastes before entering a municipal system in the textile, canning, paper,

edible oil, and other industries. Lagoons have received favorable consideration because the cost is low compared to that of other types of treatment.

Chemical Treatment

The treatment usually recommended for textile waste has been chemical treatment, whether in combination with physical treatment (lagooning) as pretreatment before entering a municipal sewage system, or as the only treatment. This method has shown through the years that it can do the job if handled correctly. Of course, a coagulant which worked on the wastes when the plant started may not necessarily work now as plant operations change. Also the major drawback in a lot of cases has been the cost.

Chemical treatment is usually thought of under three headings: pH adjustment, whether with carbon dioxide, acid, alkali, etc.; coagulation and precipitation; and oxidation, with air, chlorine, etc. Certain facilities are necessary for each, as follows:

pH adjustment—equalization basin, recorders, pH meters, feed controls, chemicals, mixing chambers, etc.

Coagulation and precipitation—equalization basin, clarifier, chemicals, chemical feed facilities, recorders, controls, etc.

Oxidation—equalization basin, source of air or chlorine, recorder, chlorinator, diffuser system, contact chamber, etc.

The key to the best and most successful operation is using the right chemical or chemicals for the particular waste. In general, the most often used chemicals are lime, alum, copperas, chlorine, sulfuric acid, or a combination of these. Another important point is where to add the chemicals. Metallic coagulants are added at the rapid-mix basin, acid ahead of or at the rapid-mix basin, and lime at the rapid-mix basin if used as a coagulant. When lime is used with the metallic coagulants for pH adjustment it should be added either ahead of or after the rapid-mix basin. With lime the sequence of addition with respect to the coagulating agent often makes the difference between success or failure of the treatment. If the floc formation is slow, adding lime ahead of the coagulant may improve this condition. When copperas is used, adding lime afterwards causes a heavier floc. Addition of lime after the coagulant also often improves B.O.D. and color removal (13).

Control of pH is usually used as a prelude to some other treatment. The waste is either acid or alkaline and chemicals are added to bring the waste near the neutral point for biological treatment or to the best pH range for coagulation.

Chemical oxidation is used on wastes of an organic nature. Air or chlorine can be used. The air will drive off the odor-producing gas before it oxidizes the organic wastes. Chlorine will immediately reduce odors and oxidize the organic portion of the wastes. Chemical oxidation is almost always used in conjunction with other treatment methods as a pretreatment to make the waste more treatable or as post-treatment as a form of effluent polishing. If air is used in conjunction with biological life it constitutes biological oxidization and is not covered under this heading.

Biological Treatment

The process of biological treatment (14)(15) is normally carried on in two ways: by the trickling filter and/or the activated sludge process. Both methods are based on the same idea—biological life fed by oxygen and liquid wastes using up the organic matter in the liquid wastes and leaving a clean product.

Trickling Filter—The trickling filter is a process in which the waste is treated by spraying over a bed of

stone. A gelatinous film developed on the surface of the stone oxidizes the organic material in the waste as it trickles over the stone. The waste may be circulated through the filter bed more than once. This gives the filter the capacity to take care of a larger volume of waste and a higher organic loading than in a filter which has no recirculation.

Activated Sludge—Conventional activated sludge treatment consists of mixing waste with 20 to 35 per cent of its volume of biologically active sludge, then agitating this mixture with air or in the presence of air. The suspended matter is then allowed to settle and the clear liquor is discharged. The sludge is biologically active and contains a large number of aerobic and facultative bacteria. It is developed by continuous aeration of untreated sewage and sludge for a period of several weeks. The air is passed into the mixture in the form of small bubbles which furnish oxygen for the bacteria. The process of making this sludge is called activation and the sludge, activated sludge.

Pilot-Plant Experiments

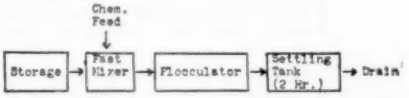
Pilot plants of various kinds and types were operated to determine different treatment methods. The first type investigated was lagooning.

Physical Treatment

To simulate actual lagooning conditions, 60-gal. wooden drums were set up outside the laboratory in the sun. These drums had a water depth of 3 to 4 ft. to equal the depth of a shallow lagoon. The waste to be treated was placed in the drum, mixed well, and then a sample was collected to be analyzed. At regular intervals the drums were resampled. This procedure was carried on until it could be seen that either no reduction in pollution characteristics was to be noted or the waste gave the same analysis several times in a row, showing a static condition had been reached. Each time a sample was collected the odor at each barrel was noted, then the contents were stirred to see if that would increase the odor. The various dye wastes and sewage and mill wastes mixtures were all examined.

Chemical Treatment

To study chemical treatment it was necessary to design and set up a laboratory-size chemical treatment plant. This plant was made up of the following units:



The flow could be regulated to give various retention times in the settling tank and was usually operated at approximately 1 g.p.h. to give a 2-hr. settling period. Beaker coagulation tests were made to determine the various chemical dosages necessary for coagulation and precipitation. A beaker test also was run simultaneously with each pilot-plant run, and the results compared very well.

The plant was started up and allowed to run 2 to 3 hr. before samples were collected. This allowed for any adjustments necessary to the flows, liquid chemical feeds, mixer, and flocculator. The chemicals were all fed continuously, as either liquids or slurries. The slurries were continuously mixed with a mechanical stirrer to insure a representative concentration at all times, and also to guard against feed clogging. Various chemicals and combinations of chemicals were tried to see which gave the best reduction in color and B.O.D.

Biological Treatment

The biological treatment plants used in these experiments have already been described in detail in previous papers. Therefore, only a brief description is given here.

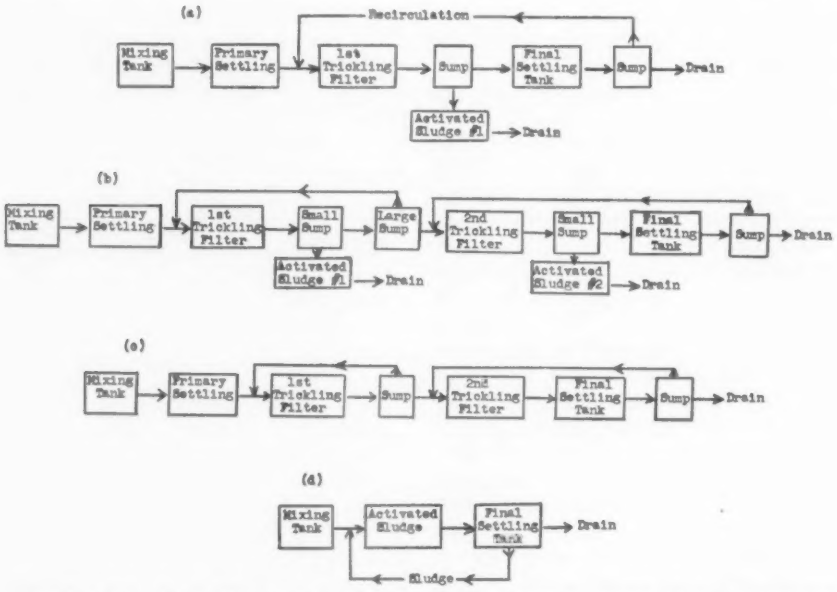


FIGURE 1.—Flow diagrams of (a) and (b) combined treatment of mill waste and sewage, (c) separate treatment of mill waste and sewage seed, and (d) separate treatment of sewage.

Both the high-rate trickling filter and activated sludge processes were investigated, separately and in combination.

The trickling filter pilot plant consisted of the units shown in Figure 1.

The filters consisted of two 1¼-ft. diameter terra cotta pipes; the medium in the No. 1 filter being broken granite chips and in the No. 2 filter Birmingham slag. Both met the North Carolina State Board of Health trickling filter specifications. The flow on the filters was varied from 125 to 250 g.p.d. The settling tanks had adjustable overflows to change capacities, with flows to insure 2-hr. settling time.

The three small activated sludge units were arranged so that two could operate in combination with the filters as a one-stage trickling filter and activated sludge unit and as a two-stage trickling filter and activated sludge unit with the third unit as a control. The activated sludge units were small, so that the loss of the volume removed from the filter effluent for activated sludge treatment would not affect the subsequent filter and/or final settling. Each activated sludge unit had a volume of 2,000 c.c. and contained an aerator consisting of a perforated copper tube wound with glass yarn. The aerator extended along the whole side of the aeration tank and gave the sludge a cross-roll effect.

The final settling tank was built into one end of the aerator, causing the fine sludge to slide back into the aeration compartment of its own accord. The heavy sludge was returned hourly by suction bulb to the head end of the aerator. Due to the small size of the units, sludge return usually was 100 per cent. The best results were found on treatment of mill wastes mixtures with a suspended solids content of 7,000 to 9,000 p.p.m., approximately three times normal sewage plant practice.

With the various pilot plants the following experiments were run:

1. One-stage high-rate trickling filter and final settling.
2. Two-stage high-rate trickling filter and final settling.
3. One-stage high-rate trickling filter and activated sludge.
4. Two-stage high-rate trickling filter and activated sludge.
5. Activated sludge.

All these units were operated 24 hr. a day and seven days a week.

Pilot-Plant Results

The main thing all of these pilot-plant experiments proved was that textile wastes could be treated satisfactorily in a number of ways.

Table I is a breakdown of the wastes flow at Cone Mills, and Table II is a breakdown of domestic sewage and mill wastes at the North Buffalo sewage plant. The mills are connected to the municipal sewers and the pipeline runs between the mills along the creek bank. The sewage and mill wastes are given chemical treatment and sedimentation at the sewage treatment plant; a 6.5-m.g.d. activated sludge plant operating at present as an overloaded chemical treatment plant. The activated sludge units are not currently in operation.

Although four separate mills are located at the Greensboro site, some wastes are duplicated from mill to mill. Any effort to segregate the wastes for separate treatment of each specific waste was not considered, due to the volume of flow and the expense involved in changing pipe layout. Also, there seems to be no point in segregating the wastes unless this practice would allow a large volume of wastes to be disposed of with no treatment, which is not the case.

The experiments did not go into the complete cost of segregation of wastes, although chemical coagulation tests were run on the separate wastes to see how that cost would compare with treatment of the combined wastes. The problem was to see how the wastes could be treated in the most efficient way at the lowest cost. The following possibilities were investigated:

TABLE II.—Flow to Sewage Plant

Source	B.O.D. (lb./day)	Flow (m.g.d.)	Per Cent of Flow
Sewage	10,230	5.61	—
Unidentified wastes*	4,670	1.24	—
Total sewage	14,900	6.85	61.10
Mill wastes	20,856	4.36	38.90
Total	35,756	11.21	100.0

* Not directly traceable to mill outlets, so included under domestic sewage for these experiments. Experiments in progress include the unidentified wastes under mill wastes, thus changing the percentage from 40–60 to 50–50 mill wastes-sewage.

TABLE I.—Mills' Textile Wastes

Plant No.	Outlet No.	Type of Waste	Flow (m.g.d.)	B.O.D. (lb./day)	B.O.D. (p.p.m.)	Per Cent of Total
1	1	Sulfur and indigo	0.212	1,820	1,028	4.86
2	2	Rayon and cotton dye waste*	0.993	1,510	381	10.90
2	3	Finishing waste†		2,760	640	11.88
3	4	Bleachery and kier waste	0.144	2,440	2,040	3.30
3 and 4	5	Kier and finishing waste; vat, sulfur, and indigo dye waste; color shop; mercerizing waste	3.011	12,320	490	69.06
Total	All	All	4.36	20,850	—	100.00

* 0.475 m.g.d. † 0.518 m.g.d.

1. Physical treatment; lagooning.
2. Chemical treatment; coagulation, precipitation, pH adjustment, oxidation.
3. Biological treatment; trickling filter, activated sludge.
4. Combination.

Physical Treatment

Table III shows the pilot-plant results of lagooning or storage of the wastes by mills, mixed mill wastes, and mill wastes and domestic sewage. In general, the experiments show that lagooning will not be successful as a method of complete treatment for this mill waste because of the large area necessary and the alkaline nature of the wastes. To give good reduction of pollutional characteristics the mill wastes separate or mixed would have to be stored almost indefinitely.

If, on the other hand, the land is available at a low cost and domestic

TABLE III.—Physical Treatment of Textile Wastes by Storage* to Simulate Lagooning

Waste	Storage Time (days)	Month	Results			
			Factor	Original	After Storage	Reduction (%)
1. Sulfur dye wastes	23	Feb.	pH	10.2	9.1	10.8
			B.O.D.	5,600	4,590	16.3
			Color	70,000	50,000	28.6
			Odor*	Sulfur dye	Sulfur dye	—
2. Sulfur and indigo dye wastes mixture, mill No. 1	14	Sept.	pH	9.8	8.9	9.2
			B.O.D.	1,156	2,000+	None
			Color	40,000	No change	None
			Odor†	Obj. (1)	—	—
3. Mixed wastes, mill No. 3 and No. 4; dye wastes, kier wastes, finishing wastes, color shop, mercerizing wastes	21	July	pH	11.7	No change	None
			B.O.D.	880	800	9.1
			Color	600	No change	None
			Odor	Not obj.	No change	—
4. Finishing wastes, mill No. 2, outlet No. 1	6	Dec.	pH	10.9	8.0	23.8
			B.O.D.	415	413	None
			Color	200	200	None
			Odor†	Obj. (6)	—	—
5. Composite mill wastes, all mills	18	Sept.	pH	11.7	10.2	12.8
			B.O.D.	894	800	10.5
			Color	500	400	20.0
			Odor†	Obj. (18 to 20)	—	—
6. Mill wastes and sewage mixture, 40 per cent mill wastes, 60 per cent sewage	10	Sept.	pH	11.4	9.2	19.3
			B.O.D.	600	477	20.5
			Odor†	Obj. (7)	—	—
	18	Sept.	pH	11.3	8.8	21.2
			B.O.D.	636	443	30.4
			Color	500	400	20.0
			Odor†	Obj. (7)	—	—
	28	Sept.	pH	11.4	8.8	22.1
			B.O.D.	600	153	74.7
			Odor†	Obj. (7)‡	—	—

* Pilot-plant storage in 60-gal. wooden barrels out-of-doors in the sun.
† Numbers in ( ) are days of storage after which odor became objectionable.
‡ Only slight after 28 days.

TABLE IV.—Chemical Treatment of Individual Wastes

Dye Waste	Chemical	Amount per 1,000 Gal. (lb.)	Cost per 1,000 Gal. (¢)		Results		
					pH Change	Color Red. (%)	H_2S
Aniline black*	Alum	0.9	2.2				
	Lime	0.4	0.38	2.58	6.5 to 7.0	83.8	
	$FeSO_4$	2.3	3.04				
	Lime	0.6	0.58	3.62	6.5 to 6.9	80.0	
	$FeCl_3$	1.5	8.8				
	Lime	0.6	0.58	9.38	6.5 to 7.7	83.8	
	Lime	6.3	—	6.05	6.5 to 11.7	80.0	
Developed dyes*	$FeSO_4$	11.6	15.3				
	Lime	2.1	2.0	17.3	3.3 to 5.6	85.0	
	$Fe_2(SO_4)_3$	18.3	38.5				
	Lime	10.5	10.0	48.5	3.3 to 7.0	65.0	
Direct dyes*	$Fe_2(SO_4)_3$	2.8	—	5.9	10.8 to 3.6	75.0	
	Alum	7.4	—	18.0	10.8 to 4.3	75.0	
	$FeCl_3$	3.4	—	19.8	10.8 to 3.5	85.0	
	$FeSO_4$	3.5	4.6				
	Lime	52.3	50.0	54.6	10.8 to 11.9	90.0	
Indigo	Lime	7.0	—	6.7	10.5 to 11.8	65.0	
	$FeSO_4$	5.8	7.65				
	Lime	12.5	12.0	17.65	10.5 to 11.5	94.5	
	Alum	10.0	—	24.0	10.5 to 4.2	65.0	
	$CaCl_2$	154.0	—	285	10.5 to 8.2	94.5	
Naphthol*	H_2SO_4	21.8	—	20.2	11.6 to 4.5	99	
	$Fe_2(SO_4)_3$	27.8	—	58.5	11.6 to 6.0	99.5	
	Alum	55.8	—	136	11.6 to 4.5	99.5	
	$FeCl_3$	33.9	—	198	11.6 to 5.6	99.5	
Sulfur	H_2SO_4	36.5	—	33.4	11.7 to 3.5	99.0	+
	Alum	58.0	—	141	11.7 to 5.0	99.0	+
	$FeSO_4$	214	—	282	11.7 to 8.3	99.7	−
Vats*	$FeSO_4$	92.8	122				
	Lime	12.5	12	134	11.7 to 11.1	85.0	
	$FeSO_4$	116	—	153	11.7 to 11	87.5	
	Alum	232.5	—	565	11.7 to 6.3	87.5	

* Reference 6.

sewage can be mixed with the mill wastes it will be successful at a low capital cost. The domestic sewage dilutes and seeds the wastes with biological life and shortens the storage time necessary for treatment. The lagoons must be located away from populated areas, however, due to the presence of some odors. Land cost and mill locations hinder this method in this area. The results of these experiments then show that lagooning or physical treatment can best be used as a flow and pollution load equalizer prior to secondary treatment.

Chemical Treatment

Tables IV, V, and VI show the results of chemical treatment on the various separate dye wastes, mixed dye wastes by mills, and composite mixed mill wastes. Tables VII and VIII explain the cost of the chemicals for treatment of (a) separate wastes, by

TABLE V.—Chemical Treatment of Wastes Separately by Mills

Mill	Chemical	Amount per 1,000 Gal. (lb.)	Cost per 1,000 Gal. (¢)		pH Change	Removals (%)	
						B.O.D.	Color
No. 1. Sulfur and indigo	$FeSO_4$	5.85	7.8	13.4	10.2 to 10.2	41.5	91.0
	Lime	5.85	5.6				
	Lime	20.9	—	20	10.2 to 11.6	—	99
	Alum	20.9	51	57	10.2 to 6.0	43.7	97.5
	Acid	6.5	6				
	$CaCl_2$	24.6	—	60	10.2 to 8.4	42.5	85.0
	Alum	37.2	—	91	10.2 to 6.2	—	99.4
No. 2. Finishing waste	Acid	2.0	—	1.85	10.8 to 8.5	None	None
	$FeSO_4$	4.2	5.55	9.55	10.8 to 10.0	50.0	80.0
	Lime	4.2	4.0				
No. 3. Kier waste	$FeSO_4$	145.0	192	204	11.8 to 9.2	—	98.0
	Lime	12.6	12				
	Alum	83.7	204	210	11.8 to 6.2	—	99.0
	Acid	6.5	6				
	Alum	130.2	—	315	11.8 to 5.0	—	99.5
Nos. 3 and 4. Lagoon, kier finishing, dyeing, color shop, mercerizing	$FeSO_4$	4.2	—	5.5	11.7 to 9.8	18.9	None
	$FeSO_4$	8.2	10.82	16.77	11.7 to 9.5	41.2	50
	Lime	6.2	5.95				
	$CaCl_2$	10.0	—	24.4	11.7 to 10.15	49.5	60
	Alum	16.7	40.8	45.2	11.7 to 6.3	60.0	82.5
	Acid	4.7	4.4				
No. 4. Dyeing, finishing	$FeSO_4$	5.85	—	7.75	11.0 to 10.2	42.2	80
	$FeSO_4$	4.2	5.55	9.55	11.0 to 11.0	52.5	80
	Lime	4.2	4.0				
	$CaCl_2$	7.5	—	13.8	11.0 to 10.8	49.0	84
	Alum	16.7	40.8	47.0	11.0 to 5.7	56.9	90
	Acid	6.7	6.2				

TABLE VI.—Chemical Treatment of Mixed Mill Wastes*

Chemical	Amount per 1,000 Gal. (lb.)	Cost per 1,000 Gal. (¢)		Results		
				pH Reduction	Removal (%)	
					B.O.D.	Color
Copperas	4.2	5.6		12.0 to 10.6	20	50
	7.8	10.3		12.0 to 10.4	30	70
Copperas	5.8	7.65	14.2	12.0 to 11.7	59.5	83.5
Lime	5.8	5.55				
$CaCl_2$	8.4	15.5		12.0 to 10.8	47.5	83.0
Alum	8.4	20.5	23.7	12.0 to 6.0	40	83.0
Acid	3.5	3.2				
Alum	12.0 to 14.2	29.3 to 34.6	33 to 38	12.0 to 6.0	60 to 70	87.5
Acid	3.5	3.2				

* Original waste mixture: pH 12.0, B.O.D. 808, color 954.

TABLE VII.—Complete Chemical Treatment Separately by Mills

Mill No.	Type of Waste	Best Treatment and Cost	Source of Extra Cost	Reduction Results (%)
1	Indigo and sulfur dye	Copperas and lime, 13.4¢ per 1,000 gal.	pH adjustment, B.O.D. reduction	B.O.D., 41.5 Color, 90
2	Finishing waste	Copperas and lime, 9.95¢ per 1,000 gal.	pH adjustment, B.O.D. reduction	B.O.D., 50.0 Color, 80-0
3 and 4	Kier waste, dye waste, color shop, mercerizing waste	Copperas and lime, 16.8¢ per 1,000 gal.	Some pH adjustment, B.O.D. reduction	B.O.D., 41.2 Color, 50
		Alum and acid, 45¢ per 1,000 gal.		B.O.D., 60.0 Color, 82.5
All*		Copperas and lime, 15.1¢ per 1,000 gal.	pH adjustment, extra B.O.D. reduction	B.O.D., 40 to 45 Color 50 to 90
	Total	Copperas and lime, alum and acid, 35.5¢ per 1,000 gal.		B.O.D., 45 to 50 Color 80 to 90

* Average cost based on total flow. Chemical coagulation cost—Extra costs include 3.5¢ per 1,000 gal. for pH adjustment and 20.0¢ per 1,000 gal. for B.O.D. removal (chlorination), making a grand total of 38.6¢ per 1,000 gal. for copperas and lime and 59.0¢ per 1,000 gal. for copperas and lime and alum and acid.

mills, and (b) the composite mill wastes. The chemical coagulants will remove between 40 and 70 per cent of the B.O.D. and 80 to 90 per cent of the color. This will not be enough reduction in the total pollutional load for a small stream; therefore, chemical oxidation is necessary.

Chlorination is the fastest means of chemical oxidation; it will remove 30 to 40 per cent of the B.O.D. almost immediately. When chemical coagulation is followed by chlorination and lagooning, a final pH adjustment is necessary before the wastes can be discharged. Lagooning will allow the solids precipitated by the chlorine to settle out over several days. This will remove 70 to 80 per cent of the remaining solid matter in the wastes. The complete chemical treatment will consist of coagulation and precipitation, chlorination, lagooning, and final pH adjustment.

Treatment will cost \$0.39–\$0.59 per 1,000 gal. (Table VII). The total chemical cost, therefore, would amount to approximately \$1,700–\$2,570 on 4.36 m.g.d. for complete treatment. This cost, plus treatment facilities for chemical coagulation, pH adjustment, and B.O.D. reduction, would make chemical treatment of each mill's waste very expensive.

The construction cost and daily fixed cost would be approximately the same

TABLE VIII.—Complete Chemical Treatment of Combined Mill Wastes

Treatment	Cost per 1,000 Gal. (¢)*	Extra Cost	Reduction (%)	
			B.O.D.	Color
Copperas and lime	14.2	pH adjustment, B.O.D. reduction	60.0	80 to 90
Alum and acid:				
No. 1	23.7	—	40.0	80 to 90
No. 2	33 to 38	—	60 to 70	80 to 90

* Chemical coagulation cost. Extra costs include 2.3¢ per 1,000 gal. for pH adjustment and 20.0¢ per 1,000 gal. for B.O.D. removal (chlorination), making a grand total of 36.5¢ per 1,000 gal. for copperas and lime and 46¢ to 57.8¢ per 1,000 gal. for alum and acid.

TABLE IX.—Comparative Costs for Various Types of Treatment

Cost Item	Treatment Cost by Mills ($)		Combined Treatment Cost, One Plant ($)
	One Plant	Three Plants	
Construction	1 to 1.5 × 10^6	3 to 4.5 × 10^6	1 to 1.5 × 10^6
Fixed daily	2 to 3 × 10^2	4 to 8 × 10^2	2 to 3 × 10^2
Daily chemical:			
Per 1,000 gal.	0.39—0.59	0.39—0.59	0.365 to 0.578
For 4.36 m.g.d.	1,700—2,570	1,700—2,570	1,600 to 2,520
Total daily	1,950—2,820	2,300—3,170	1,850 to 2,770

for treatment of the combined wastes or if all the wastes were piped to one point for separate treatment. However, if three or four separate treatment plants were built the cost of construction would be three to four times higher (Table IX).

It can be seen that chemical treatment of mixed mill wastes would be cheaper than chemical treatment of the mill wastes separately by mills if all wastes require treatment and none of them can be segregated without treatment. The B.O.D. removals are given in Table X.

Use of carbon dioxide for pH adjustment is cheaper than acid. Table XI shows the cost of carbon dioxide production for 40,000 lb. of carbon dioxide gas compared with acid cost.

Biological Treatment

Biological treatment of these textile mill wastes has been investigated from several standpoints, as follows:

1. Biological treatment of the organic dye wastes mixed with sewage for seed.
2. Biological treatment of the total waste mixture with sewage seed and pH adjustment.
3. Biological treatment of the total waste mixture and the total sewage flow at the North Buffalo sewage treatment plant.

Tables XII and XIII give the results from the treatment of a sulfur and indigo mixture from Mill No. 1 with domestic sewage. This waste mixture was treated first on a high-rate

TABLE X.—Comparison of Separate and Combined Treatments

Item	Mill No. 1	Mill No. 2	Mills Nos. 3 and 4*	Combined Wastes	
Flow (m.g.d.)	0.212	0.973	3.155	4.36	
B.O.D. load, total (lb.)	1,820	4,270	12,320	24,029	
B.O.D. removal:					
By coagulation:					
(%)	41.5	50	50	40 to 50	60 to 70
(lb.)	755	2135	6,160	10,873	15,619
By chlorination:					
(%)	30	30	30	30	30
(lb.)	319.5	641	1,848	3,947	2,523
By lagooning:					
(%)	75	75	75	75	75
(lb.)	559	1124	3,234	6,897	4,415
Total B.O.D. load to creek:					
(lb.)	186	367	1,078	2,312	1,470
(p.p.m.)	105	45.2	40	63.5	40.5

* Average values.

TABLE XI.—Comparative Costs for Treatment with CO_2 Stack Gas, Produced CO_2 in Submerged Burners, and Acid

Cost Item	CO_2 Cost, Stack Gas ($)	Production Cost for CO_2 ($)	Acid Cost ($)
Equipment	100,000	90,000 to 100,000	100,000
Installation	50,000 to 100,000	50,000 to 150,000	100,000 to 200,000
Chemical	—	—	0.08 to 0.10
Operating, per day	30	218*	200
Per 1,000 gal. treated	0.01†	0.073†	0.167†
Per day, 4.36 m.g.d.	43.60	318.28	728.12

* Electricity $30, fuel $188.
† Plus equipment and installation.

TABLE XII.—Pilot-Plant Reduction (%) of a Sulfur and Indigo Dye Wastes and Domestic Sewage Mixture by Two-Stage High-Rate Trickling Filter and Final Settling*

Date (1955)	Primary†		First-Stage Filter‡		Second-Stage Filter¶		First- and Second-Stage Filters and Final Settling	
	B.O.D.	Color	B.O.D.	Color	B.O.D.	Color	B.O.D.	Color
(*a*) 25 Per Cent Dye Wastes, 75 Per Cent Sewage§								
May 12	14.9	0	5.6	22.2	63.6	14.3	70.6	33.3
13	11.95	0	34.4	15.0	37.3	26.5	63.8	37.5
18	0	0	15.4	22.2	26.5	35.8	40.6	50.0
19	8.9	0	4.5	18.8	52.8	38.5	63.8	50.0
20	0	0	52.0	22.2	50.3	28.6	76.2	44.9
25	23.6	0	0.5	16.7	51.0	20.0	62.9	33.3
26	13.9	0	10.9	14.3	61.5	25.0	74.2	35.7
27	0	0	28.2	12.5	57.5	14.3	72.9	25.0
June 1	0	0	41.0	41.6	49.7	42.8	83.6	66.6
2	0	0	37.6	12.5	42.6	20.0	64.3	30.0
3	0	0	37.0	20.0	44.2	25.0	69.0	40.0
8	0	0	42.8	44.8	21.5	30.0	89.9	85.8
9	18.1	0	22.0	18.4	78.8	20.0	89.0	34.7
10	4.3	0	56.5	20.0	55.1	20.0	86.5	36.0
Avg.	5.5	0	32.3	21.8	50.0	23.9	68.0	40.0
(*b*) 75 Per Cent Dye Wastes, 25 Per Cent Sewage**								
June 30	0	0	19.1	25.0	39.7	0	48.5	41.6
July 1	6.6	0	19.5	18.8	19.4	0	43.7	25.0
6	0	0	12.5	40.5	62.0	0	75.8	50.0
7	14.6	0	26.0	12.5	29.2	0	57.7	25.0
8	—	0	—	25.0	—	0	—	—
13	17.0	0	31.2	14.3	14.0	33.3	54.0	42.9
14	0	0	11.4	28.6	25.4	20.0	55.1	42.9
15	0	0	19.9	28.6	37.5	20.0	51.7	42.9
Avg.	5.5	0	19.9	24.1	28.2	9.2	55.2	38.6

* No pH adjustment, recirculation 2:1 at 110 g.p.d.
† Based on raw influent.
‡ Based on effluent from primary clarifier.
¶ Based on effluent from first-stage filter.
§ Filter B.O.D. load, 1.8 lb. per cubic yard on first stage, 1.12 on second stage.
** Filter B.O.D. load 3.28 lb. per cubic yard on first stage, 2.52 lb. per cubic yard on second stage.

TABLE XIII.—Pilot-Plant Treatment of a Mixture of Sulfur and Indigo Dye Wastes with Domestic Sewage by the Activated Sludge Process*

Date (1954)	Dye Waste Mixture (%)	Removal (%)	
		B.O.D.	Color
June 8	6	83.6	76.0
9	8	76.5	75.0
10	10	84.0	62.5
15	12	66.4	64.3
16	14	86.2	68.8
17	16	83.3	62.5
22	20	82.6	50.0
30	30	65.4	53.8
July 1	32	82.5	37.5
8	38	89.5	40.0
14	48	72.0	60.0
15	50	43.6	25.0
21	50	37.7	83.3
22	50	14.2	10.0

* Aeration time, 6 hr.

trickling filter. The results indicate that the waste is treatable on high-rate filters, but will cause extensive odors. Therefore, this method would not be advisable. The activated sludge process also was tried. It was found that a 20 to 30 per cent mixture of sulfur and indigo dye waste could be treated successfully with domestic sewage, but above that amount the sludge absorbs so much dye it dies and the treatment fails. The next two pilot-plant experiments involve the merits of combined and separate treatment of textile mill wastes and domestic sewage.

Separate treatment, as used in this paper, means that the mill wastes mixture was treated in one process or system and the domestic sewage in another. The industrial wastes, in this case highly alkaline textile mill wastes, will have the pH adjusted with acid down to 8.3, then just enough domestic sewage will be added to serve as seed material for biological treatment. In many cases nutrients are necessary and helpful. They are added as phosphates and/or nitrates. Textile wastes usually contain both phosphates and nitrates, so in this case no additives are needed. The rest of the domestic sewage, the part not needed for seeding, will normally be treated either by trickling filter or activated sludge. Both were investigated, but in this comparison activated sludge was used because it gave better results.

Combined treatment is taken to mean that the mill wastes and sewage are mixed together and treated as one.

The mill wastes and sewage mixture was treated through the high-rate filters, then the effluents from the filters were treated in the activated sludge units. The effluent from filter No. 1 was treated through activated sludge unit No. 1 and the effluent from filter No. 2 was treated through activated sludge unit No. 2. This allows comparison between first- and second-stage trickling filter-activated sludge units, plus a comparison of these methods against separate treatment.

In separate treatment, chemical coagulation could be used in place of pH adjustment to increase the removal. In this case, however, pH adjustment was used as the cheapest method of preparing the wastes for biological treatment.

Under combined treatment of 40 per cent textile wastes with 60 per cent sewage, without chemical pretreatment, through one-stage trickling filter and activated sludge, the following results were obtained:

Item	Value
Pilot-plant flow (g.p.d.)*	125
B.O.D. load (lb.)*	43,991
B.O.D. load (lb./cu. yd.)*	2.73
B.O.D. removal (%)	93.2
B.O.D. removal (lb.)*	41,111
B.O.D. to creek (lb.)*	2,880
B.O.D. to creek (p.p.m.)	31

* Based on 11.2 m.g.d. flow.

The same mixture, but treated in two-stage filters and activated sludge, provided the results given in Table XIV.

TABLE XIV.—Pilot-Plant Results on Mixture of 40 Per Cent Textile Wastes and 60 Per Cent Sewage Treated in Two-Stage Trickling Filters and Activated Sludge

Flow (g.p.d.)	B.O.D. Load		B.O.D. Removal		Effluent B.O.D.	
	(lb.)	(lb./cu. yd.)	(%)	(lb.)	(lb.)	(p.p.m.)
125	42,497	1.24	97.4	41,397	1,100	11.7
150	52,117	1.73	97.2	50,677	1,440	15.5
210	30,448	1.43	91.3	27,828	2,620	28.0

Treatment of textile mill waste (16 per cent sewage seed) separately with chemicals and two-stage filtration followed by final settling gave only fair results. B.O.D. removal was only 77.4 per cent for a loading of 1.54 lb. per cubic yard, and an effluent B.O.D. of 125 p.p.m. In addition to this pollution, there also would be pollution from the treated sewage going to the creek, amounting to 1,137 lb. or 22.7 p.p.m. in a 6-m.g.d. flow. The total effluent going to the creek from separate treatment of textile mill waste and domestic sewage by the proposed method would not be acceptable (Table XV).

The foregoing results show that effluent from combined wastes treatment, without chemicals, would be better than the treatment of each waste separately. Also the treatment of the wastes separately would have a chemical cost of $350 to $400 per day, or $90,000 to $100,000 per year.

Conclusions

1. The wastes load to be treated can be reduced by several methods, including:

(a) Closer process control and process modification.
(b) Substitution of chemicals.
(c) Chemical recovery and re-use.
(d) Good housekeeping practices.

2. A lagoon can well be used as an equalizing basin and in addition assists in removal of B.O.D. and color, as well as reduction in alkalinity.

3. The chemical treatment of textile wastes can be expensive. The most economical results were found on a combined wastes mix rather than on the coagulation of each waste separately.

4. Two methods of treating highly alkaline textile mill wastes in biological processes have been evaluated:

(a) Treating combined mill wastes and domestic sewage, without expensive chemical pretreatment, in a trickling filter-aeration process.
(b) Treating mill wastes separately, seeded with sewage, by reducing pH with expensive chemicals and passing through high-rate trickling filters.

TABLE XV.—Combined Results of Separate Treatment

Waste	B.O.D. Load*		B.O.D. Removal*		B.O.D. to Creek*	
	(lb.)	(lb./cu. yd.)	(%)	(lb.)	(lb.)	(p.p.m.)
Textile	24,029	1.54	77.4	18,979	5,050	125.0
Sewage	15,800	—	93.0	14,663	1,137	22.7
Total	39,829	—	—	33,642	6,187	66.1

* Based on 11.2 m.g.d.

5. Results from pilot-plant studies indicate that treatment of highly alkaline textile mill waste by trickling filter and activated sludge is better when combined with domestic sewage than when textile waste is treated separately from sewage.

6. When the highly alkaline textile mill waste was treated combined with domestic sewage without chemical pretreatment, through both trickling filter and aeration processes, the pollution of the resulting effluent was reduced sufficiently to be acceptable to a small receiving stream. When the highly alkaline textile mill waste was treated separately from domestic sewage, through trickling filter only, without aeration, but after expensive chemical pretreatment, the resulting effluent was not acceptable for release to a small receiving stream without additional treatment.

Experiments in Progress

Field experiments are being conducted on lagooning of mill waste with and without seeded sewage, to determine effect in reduction of B.O.D., color, and alkalinity.

Experiments also are in progress comparing results on 1.25-ft. diameter filters inside the laboratory against 4-ft. filters out-of-doors, with results thus far showing less than 3 per cent difference.

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SEWAGE STERILIZATION

Preliminary experimental studies by the Armour Research Foundation, Chicago, under a contract with the Army Chemical Corps Biological Warfare Laboratory, Fort Detrick, Md., indicate that sterilization of sewage or waste by irradiation is feasible. Experimental work showed that a suspension of a virus and a bacterial spore could be completely sterilized by isotope irradiation (primarily gamma rays). About 2,000 times as much radiation is required to kill a bacterial spore as is fatal to man.

By passing the waste between the reactor and the thermal shield, as a secondary coolant, rather than through the reactor core, the cost of sewage sterilized was estimated to be about one-quarter of a cent (2.5 mills) per gallon. This method takes advantage of available heat.

Studies indicate at present that waste sterilized by irradiation would not constitute a public health menace. More research and development will be necessary if the process is to be used on a large scale.

Stream Pollution

MODIFIED RIVER SAMPLING FOR COMPUTING DISSOLVED OXYGEN SAG

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This paper describes a project which was undertaken in an effort to determine a practical minimum number of samples required to determine the dissolved oxygen depletion in a stream by the statistical methods of Churchill and Buckingham (1). A section of the Neuse River in Wake and Johnston Counties near Raleigh, N. C., was chosen for sampling. The Neuse River has two tributaries, Crabtree Creek and Walnut Creek, each of which carries raw sewage and waste from Raleigh. These two streams enter the main river close enough together so that they can be considered as one pollution source.

Sample Collection Procedure

Six stations were established along the river at the locations indicated in Figure 1. At each site a sample was collected beneath the surface at midstream and approximately at middepth. The temperature and dissolved oxygen were measured and recorded at the time of sampling. Collected samples were then carried to the laboratory where dissolved oxygen and B.O.D. determinations were made. The dissolved oxygen and 5-day, 20° C. B.O.D. determinations were made in accordance with the procedures outlined in the tenth edition of "Standard Methods for the Examination of Water, Sewage and Industrial Wastes" (2). A total of five samples were collected at each station.

Flow Determinations

A stage-discharge relationship was established at each sampling site. A fixed reference point was established above the water surface and current meter measurements made at various stages to determine a stage-discharge curve. At the time of sampling, the distance from the reference point to the water surface was measured and the corresponding discharge determined from the stage-discharge curve.

Calculations

The tables and values for calculating the coefficients in the multiple linear correlation were set up in a manner similar to that used by Churchill and Buckingham (1). Basic data are presented in Table I. Coefficients were determined (Appendix) using the data from the first three observations (Table II). Also coefficients were determined using the first four observations, and then from all five observations (Tables III and IV). Each set of coefficients was "tested" to compare the calculated with the observed values. These results are shown in Table V.

The calculations, using selected values from Churchill and Buckingham's data, are presented in Tables VI and VII. Calculations using three selected observations in this study are given in Tables V and VIII.

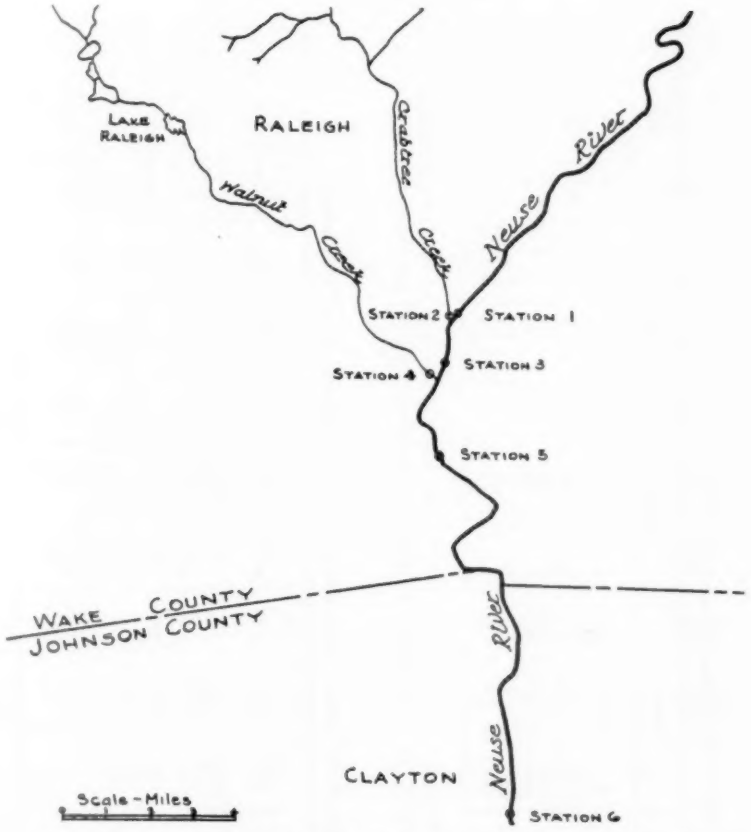

FIGURE 1.—Sampling stations on the Neuse River in North Carolina.

Discussion

A minimum or maximum value of the three variables occurred in only three of the five sample observations made in this study. The coefficients, as determined by using the first three observations, reproduced the first three observed values well but did not produce the observed dissolved oxygen drop in the fourth and fifth observations. Coefficients, computed from four observations, reproduced the first four observed values but not the fifth, although the results in this case were substantially better than those using only three observations. The coefficients obtained by using all five observations reproduce the observed values extremely well (Table V).

It is, therefore, apparent that the range of the variables involved in the determination of the coefficients is the critical factor to consider rather than the number of observations. The distribution of the values may be assumed to effect the accuracy of reproducing observed data.

In support of this finding, six observations were selected from the data presented by Churchill and Buckingham (1). These observations were critical values as far as B.O.D. at the

TABLE I.—Basic Data—Neuse River, N. C.

Date (1956)	Station 1				Station 2				Station 3				Station 4				Station 5				Station 6			
	Temp. (°C.)	D.O. (p.p.m.)	B.O.D. (p.p.m.)	Disch. (c.f.s.)	Temp. (°C.)	D.O. (p.p.m.)	B.O.D. (p.p.m.)	Disch. (c.f.s.)	Temp. (°C.)	D.O. (p.p.m.)	B.O.D. (p.p.m.)	Disch. (c.f.s.)	Temp. (°C.)	D.O. (p.p.m.)	B.O.D. (p.p.m.)	Disch. (c.f.s.)	Temp. (°C.)	D.O. (p.p.m.)	B.O.D. (p.p.m.)	Disch. (c.f.s.)	Temp. (°C.)	D.O. (p.p.m.)	B.O.D. (p.p.m.)	Disch. (c.f.s.)
Jun. 26	25.8	4.7	2.6	140	25.8	0	18	30	26.8	2.4	7.4	170	25.2	0	38	14	26.8	2.4	6.0	220	27.0	4.1	3.1	215
Jun. 30	29.0	8.6	6.0	125	27.5	0	31	15	29.0	6.3	6.8	140	28.5	0	43	10	29.0	4.9	7.4	183	29.0	10.3	6.1	200
Jul. 4	28.0	5.3	1.4	132	26.0	0.6	13	33	27.0	2.6	5.0	165	24.8	0.8	11	48	26.5	0.1	5.6	285	27.5	2.6	4.0	220
Jul. 22	25.5	5.6	1.2	480	26.0	3.8	6.8	84	26.0	6.0	2.3	570	26.0	1.4	69	30	26.5	5.3	1.4	630	27.0	4.5	1.9	780
Aug. 5	25.0	5.4	1.0	460	23.5	2.2	16	62	25.5	5.2	2.6	525	24.0	0	41	14	25.5	5.0	3.0	580	26.0	3.6	2.4	525

TABLE II.—Multiple Linear Correlation of D.O. Drop, B.O.D., Temperature, and Discharge Using Three Samples

Item	Dissolved Oxygen (p.p.m.)			B.O.D. at Sag (p.p.m.) X_1	Temp. (°C.) X_2	$\frac{1{,}000}{\text{c.f.s.}}$ X_3	Y^2	YX_1	YX_2	YX_3	X_1^2	X_1X_2	X_1X_3	X_2^2	X_2X_3	X_3^2
	Sta. 1	at Sag	Drop Y													
6/26/56	4.7	2.4	2.3	6.0	26.8	4.55	5.29	13.80	61.64	10.47	36.00	160.80	27.30	718.24	121.94	20.70
6/30/56	8.6	4.9	3.7	7.4	29.0	5.46	13.69	27.38	107.30	20.20	54.76	214.60	40.40	841.00	158.34	29.81
7/ 4/56	5.3	0.1	5.2	5.6	26.5	3.51	27.04	29.12	137.80	18.25	31.36	148.40	19.66	702.25	93.02	12.32
Sums			11.2	19.0	82.3	13.52	46.02	70.30	306.74	48.92	122.12	523.80	87.36	2,261.49	373.30	62.83
Means			$\bar{Y}$ 3.73	$\bar{X}_1$ 6.33	$\bar{X}_2$ 27.43	$\bar{X}_3$ 4.51	—	—	—	—	—	—	—	—	—	—
Correction items*							$n\bar{Y}^2$ 41.74	$n\bar{Y}\bar{X}_1$ 70.83	$n\bar{Y}\bar{X}_2$ 306.94	$n\bar{Y}\bar{X}_3$ 50.47	$n\bar{X}_1^2$ 120.21	$n\bar{X}_1\bar{X}_2$ 520.89	$n\bar{X}_1\bar{X}_3$ 85.64	$n\bar{X}_2^2$ 2,257.21	$n\bar{X}_2\bar{X}_3$ 371.12	$n\bar{X}_3^2$ 61.02
Corrected sums							4.28	−0.53	−0.20	−1.55	1.91	2.91	1.72	4.28	2.18	1.81

* n = number of observations.

TABLE III.—Multiple Linear Correlation of D.O. Drop, B.O.D., Temperature, and Discharge Using Four Samples

Item	Dissolved Oxygen (p.p.m.)			B.O.D. at Sag (p.p.m.)	Temp. (°C.)	1,000 c.f.s.										
	Sta. 1	at Sag	Drop Y	X_1		X_3	Y^2	YX_1	YX_2	YX_3	X_1^2	X_1X_2	X_1X_3	X_2^2	X_2X_3	X_3^2
6/26/56	4.7	2.4	2.3	6.0	26.8	4.55	5.29	13.80	61.64	10.47	36.00	160.80	27.30	718.24	121.94	20.70
6/30/56	8.6	4.9	3.7	7.4	29.0	5.46	13.69	27.38	107.30	20.20	54.76	214.60	40.40	841.00	158.34	29.81
7/ 4/56	5.3	0.1	5.2	5.6	26.5	3.51	27.04	29.12	137.80	18.25	31.36	148.40	19.66	702.25	93.02	12.32
7/22/56	5.6	4.5	1.1	1.9	27.0	1.28	1.21	2.09	29.70	1.41	3.61	51.30	2.43	729.00	34.56	1.64
Sums			12.3	20.9	109.3	14.80	47.23	72.39	336.44	50.33	125.73	575.10	89.79	2,990.49	407.86	64.47
Means			$\bar{Y}$ 3.07	$\bar{X}_1$ 5.22	$\bar{X}_2$ 27.32	$\bar{X}_3$ 3.70	—	—	—	—	—	—	—	—	—	—
Correction items*							$n\bar{Y}^2$ 37.70	$n\bar{Y}\bar{X}_1$ 64.10	$n\bar{Y}\bar{X}_2$ 335.49	$n\bar{Y}\bar{X}_3$ 45.44	$n\bar{X}_1^2$ 108.99	$n\bar{X}_1\bar{X}_2$ 570.44	$n\bar{X}_1\bar{X}_3$ 77.26	$n\bar{X}_2^2$ 2,985.53	$n\bar{X}_2\bar{X}_3$ 404.34	$n\bar{X}_3^2$ 54.76
Corrected sums							9.53	8.29	0.95	4.89	16.74	4.66	12.53	4.96	3.52	9.71

* n = number of observations.

TABLE IV.—Multiple Linear Correlation of D.O. Drop, B.O.D., Temperature, and Discharge Using Five Samples

Item	Dissolved Oxygen (p.p.m.)			B.O.D. at Sag (p.p.m.)	Temp. (°C.)	1,000 c.f.s.										
	Sta. 1	at Sag	Drop Y	X_1		X_3	Y^2	YX_1	YX_2	YX_3	X_1^2	X_1X_2	X_1X_3	X_2^2	X_2X_3	X_3^2
6/26/56	4.7	2.4	2.3	6.0	26.8	4.55	5.29	13.80	61.64	10.47	36.00	160.80	27.30	718.24	121.94	20.70
6/30/56	8.6	4.9	3.7	7.4	29.0	5.46	13.69	27.38	107.30	20.20	54.76	214.60	40.40	841.00	158.34	29.81
7/ 4/56	5.3	0.1	5.2	5.6	26.5	3.51	27.04	29.12	137.80	18.25	31.36	148.40	19.66	702.25	93.02	12.32
7/22/56	5.6	4.5	1.1	1.9	27.0	1.28	1.21	2.09	29.70	1.41	3.61	51.30	2.43	729.00	34.56	1.64
8/ 5/56	5.4	3.6	1.8	2.4	26.0	1.90	3.24	4.32	46.80	3.42	5.76	62.40	4.56	676.00	49.40	3.61
Sums			14.1	23.3	135.3	16.70	50.47	76.71	383.24	53.75	131.49	637.50	94.35	3,666.26	68.08	68.08
Means			$\bar{Y}$ 2.82	$\bar{X}_1$ 4.66	$\bar{X}_2$ 27.06	$\bar{X}_3$ 3.34	—	—	—	—	—	—	—	—	—	—
Correction items*							$n\bar{Y}^2$ 39.76	$n\bar{Y}\bar{X}_1$ 65.71	$n\bar{Y}\bar{X}_2$ 381.55	$n\bar{Y}\bar{X}_3$ 47.09	$n\bar{X}_1^2$ 108.58	$n\bar{X}_1\bar{X}_2$ 630.50	$n\bar{X}_1\bar{X}_3$ 77.82	$n\bar{X}_2^2$ 3,661.22	$n\bar{X}_2\bar{X}_3$ 451.90	$n\bar{X}_3^2$ 55.78
Corrected sums							10.71	11.00	1.69	6.66	22.91	7.00	16.53	5.27	5.36	12.30

* n = number of observations.

TABLE V.—Comparison of Values Using Various Numbers of Observations

Date	Observed D.O. Drop (p.p.m.)	Three Observations		Four Observations		Five Observations		Three Observations (Selected)	
		Calculated D.O. Drop (p.p.m.)	Difference (Cal.-Obs.) (p.p.m.)	Calculated D.O. Drop (p.p.m.)	Difference (Cal.-Obs.) (p.p.m.)	Calculated D.O. Drop (p.p.m.)	Difference (Cal.-Obs.) (p.p.m.)	Calculated D.O. Drop (p.p.m.)	Difference (Cal.-Obs.) (p.p.m.)
6/26/56	2.3	3.03	+0.73	2.66	+0.36	2.82	+0.52	4.09	1.79
6/30/56	3.7	3.38	−0.32	3.28	−0.42	3.44	−0.26	3.71	−.01
7/ 4/56	5.2	4.81	−0.39	5.44	+0.24	5.10	−0.10	4.01	−1.19
7/22/56	1.1	12.03	10.93	0.97	−0.13	1.55	+0.45	0.91	−0.19
8/ 5/56	1.8	9.22	7.42	0.63	1.17	1.20	−0.60	1.92	0.12

sag point, temperature, and flow are concerned. Comparable results were obtained using six or 24 observations in the Churchill and Buckingham data. Fifty-eight per cent of the time the differences between the observed and calculated values were less using six observations than when using 24 observations.

The same procedure was applied to the three observations that determined the critical values from the data collected on the Neuse River. When three observations were selected (Tables V and VIII), the poor distribution of the data was reflected in the reproduction of the observed values. These results showed more deviation from the

TABLE VI.—Comparison of Calculated Values Using Twenty-four Observations and Six Observations *

Date	Observed D.O. Drop (p.p.m.)	Twenty-four Observations		Six Observations	
		Calculated D.O. Drop (p.p.m.)	Difference (Cal.-Obs.) (p.p.m.)	Calculated D.O. Drop (p.p.m.)	Difference (Cal.-Obs.) (p.p.m.)
1944					
6/19	6.5	5.25	−1.25	5.97	−0.53
6/23	5.7	6.48	−0.71	6.63	0.93
7/1	7.4	6.91	−0.49	6.89	−0.51
7/5	2.4	3.99	1.59	5.37	2.97
7/15	6.3	5.73	−0.57	5.79	−0.51
7/22	7.0	6.79	−0.21	6.86	−0.14
7/26	7.4	7.36	−0.04	7.58	0.18
7/27	8.1	7.45	−0.65	7.68	−0.42
7/28	8.1	8.66	0.56	8.39	0.29
7/29	8.9	7.46	−1.44	7.62	−1.28
8/2	6.0	4.87	−1.13	5.24	0.76
8/19	9.0	8.69	−0.31	8.11	−0.89
8/26	7.3	8.14	0.84	8.17	0.87
9/2	6.0	7.15	1.15	7.08	1.08
9/20	5.7	6.63	0.93	6.72	1.02
10/18	7.2	6.39	−0.81	6.72	−0.48
10/30	7.6	7.21	−0.39	7.32	−0.28
12/5	3.4	4.88	1.48	4.61	1.21
12/21	3.6	2.92	−0.68	3.75	0.15
1945					
1/26	4.3	3.48	0.82	4.10	−0.20
3/20	4.2	4.52	0.32	4.97	0.77
5/31	5.5	6.04	0.54	6.14	0.64
6/13	6.2	5.73	0.47	6.50	0.30
7/5	3.5	4.64	1.14	5.91	1.27

* After Churchill and Buckingham, reference 1.

TABLE VII.—Multiple Linear Correlation of D.O. Drop, B.O.D., Temperature, and Discharge Using Six Selected Observations *

Item	D.O. Drop (p.p.m.) Y	B.O.D. at Sag (p.p.m.) X_1	Temp. (°C.) X_2	$\frac{10,000}{\text{c.f.s.}}$ X_3	Y^2	YX_1	YX_2	YX_3	Y_1^2	X_1X_2	X_1X_3	X_2^2	X_2X_3	X_3^2
7/28/44	8.1	9.0	23.3	26.39	65.61	72.90	188.73	213.76	81.00	209.70	237.51	542.89	614.89	696.43
8/ 2/44	6.0	4.0	20.0	10.45	36.00	24.00	120.00	62.70	16.00	80.00	41.80	400.00	209.00	109.20
10/30/44	7.6	11.0	10.5	32.26	57.76	83.60	79.80	245.18	121.00	115.50	354.86	110.25	338.73	1,040.71
12/21/44	3.6	7.0	2.0	18.42	12.96	25.20	7.20	66.31	49.00	14.00	128.94	4.00	36.84	339.30
1/ 26/45	4.3	7.0	5.0	16.95	18.49	30.10	21.50	72.88	49.00	35.00	118.65	25.00	84.75	287.30
3/ 20/45	4.2	5.0	15.5	12.90	17.64	21.00	65.10	54.18	25.00	77.50	64.50	240.25	199.95	166.41
Sums	33.8	43.0	76.3	117.37	208.46	256.80	482.33	715.01	341.00	531.70	946.26	1,322.39	1,484.16	2,639.35
Means	$\bar{Y}$ 5.63	$\bar{X}_1$ 7.17	$\bar{X}_2$ 12.72	$\bar{X}_3$ 19.56	—	—	—	—	—	—	—	—	—	—
Correction items†					$n\bar{Y}^2$ 190.18	$n\bar{Y}\bar{X}_1$ 242.20	$n\bar{Y}\bar{X}_2$ 429.68	$n\bar{Y}\bar{X}_3$ 660.74	nX_1^2 308.45	$n\bar{X}_1\bar{X}_2$ 547.21	$n\bar{X}_1\bar{X}_3$ 841.47	$n\bar{X}_2^2$ 970.79	$n\bar{X}_2\bar{X}_3$ 1,492.82	$n\bar{X}_3^2$ 2,295.56
Corrected sums					18.28	14.60	52.65	54.27	32.55	−15.51	104.79	351.60	−8.66	1,343.79

* After Churchill and Buckingham, reference 1.
† n = number of observations.

TABLE VIII.—Multiple Linear Correlation of D.O. Drop, B.O.D., Temperature, and Discharge Using Three Selected Samples

Item	Dissolved Oxygen (p.p.m.)			B.O.D. at Sag (p.p.m.) X_1	Temp. (°C.) X_2	$\frac{1,000}{\text{c.f.s.}}$ X_3	Y^2	YX_1	YX_2	YX_3	X_1^2	X_1X_2	X_1X_3	X_2^2	X_2X_3	X_3^2
	Sta. 1	at Sag	Drop Y													
6/30/56	8.6	4.9	3.7	7.4	29.0	5.46	13.69	27.38	107.30	20.20	54.76	214.60	40.40	841.00	158.34	29.81
7/22/56	5.6	4.5	1.1	1.9	27.0	1.28	1.21	2.09	29.70	1.41	3.61	51.30	2.43	729.00	34.56	1.64
8/ 5/56	5.4	3.6	1.8	2.4	26.0	1.90	3.24	4.32	46.80	3.42	5.76	62.40	4.56	675.00	49.40	3.61
Sums			6.6	11.7	82.0	8.64	18.14	33.79	183.80	25.03	64.13	328.30	47.39	2,246.00	242.30	35.06
Means			$\bar{Y}$ 2.2	$\bar{X}_1$ 3.90	$\bar{X}_2$ 27.3	$\bar{X}_3$ 2.88	—	—	—	—	—	—	—	—	—	—
Correction items*							$n\bar{Y}^2$ 14.52	$n\bar{Y}\bar{X}_1$ 25.74	$n\bar{Y}\bar{X}_2$ 180.18	$n\bar{Y}\bar{X}_3$ 19.01	$n\bar{X}_1^2$ 45.63	$n\bar{X}_1\bar{X}_2$ 319.41	$n\bar{X}_1\bar{X}_3$ 33.70	$n\bar{X}_2^2$ 2,241.33	$n\bar{X}_2\bar{X}_3$ 236.16	$n\bar{X}_3^2$ 24.88
Corrected sums							3.62	8.05	3.62	6.02	18.50	8.89	13.69	4.67	6.14	10.18

* n = number of observations.

observed values than when four and five observations were used but they showed much less deviation than the results obtained using the first three observations.

Engineering Implications

The proper timing of the collection of samples would eliminate much effort and cost in a stream study of the type proposed by Churchill and Buckingham. Future studies should be directed toward determining the proper timing.

Conclusions

The method of analysis discussed herein (Churchill and Buckingham) provides a quick and relatively simple method of predicting the dissolved oxygen deficit of a stream below the point of pollution. The range and distribution of the data collected are more important than the number of samples collected. If each sample is observed under maximum or minimum conditions of one of the three stream variables, only six samples are required to produce practical results. Additional samples may add some small degree of refinement to the results but the refinement probably would not offset the effort expended in planning, collecting, and analyzing the samples and calculating the results.

References

1. Churchill, M. A., and Buckingham, R. A., "Statistical Method for Analysis of Stream Purification Capacity." THIS JOURNAL **28**, 4, 517 (Apr., 1956).
2. "Standard Methods for the Examination of Water, Sewage and Industrial Wastes." 10th Ed., Amer. Pub. Health Assn., New York, N. Y. (1955).

APPENDIX—COMPUTATION FOR COEFFICIENTS IN THE MULTIPLE LINEAR CORRELATIONS

The following three "normal" equations are based on the principles of least squares:

$$b_1\Sigma X_1^2 + b_2\Sigma X_1X_2 + b_3\Sigma X_1X_2 = \Sigma X_1Y \quad (1a)$$
$$b_1\Sigma X_1X_2 + b_2\Sigma X_2^2 - b_3\Sigma X_2X_3 = \Sigma X_2Y \quad (1b)$$
$$b_1\Sigma X_1X_3 + b_2\Sigma X_2X_3 - b_3\Sigma X_3^2 = \Sigma X_3Y \quad (1c)$$

Computation for Coefficients for Three Samples

Substituting values from Table II in Eq. 1*a*		$1.91b_1+2.91b_2$	$+1.72b_3$	$= -0.53$	(2)
Dividing Eq. 2 by -1.91 then		$-b_1-1.523560b_2$	$-0.900524b_3$	$= +0.277487$	(3)
Multiplying Eq. 2 by -1.523560		$-2.91b_1-0.4433560b_2-2.620523b_3$		$= +0.807487$	(4)
Substituting values from Table II in Eq. 1*b*		$2.91b_1+4.28b_2$	$+2.18b_3$	$= -0.20$	(5)
	(Σ_2)	$-0.1535606b_2-0.440523b_3$		$= 0.607487$	(6)
Dividing (Σ_2) by -0.153560		$-b_2-2.868735b_3$		$= 3.956024$	(7)
Multiplying Eq. 2 by -0.900524		$-1.72b_1-2.62b_2$	$-1.548901b_3$	$= +0.477278$	(8)
Now, multiplying (Σ_2) by -2.868735		$+0.44b_2$	$+1.263744b_3$	$= 1.742719$	(9)
Substituting values from Table II in Eq. 1*c*		$1.72b_1+2.18b_2$	$+1.81b_3$	$= -1.55$	(10)
Adding Eqs. 8, 9, and 10	(Σ_3)		$1.524843b_3$	$= -2.815441$	(11)
Solving for b_3				$b_3 = -1.846381$	
Substituting value of b_3 in Eq. 7		$-b_2-2.868735(-1.846381)$		$= 3.956024$	
Solving for b_2				$b_2 = 1.340754$	
Substituting values of b_3 and b_2 in Eq. 3		$-b_1-1.523560(1.340754)-0.900524(-1.846381)$		$= +0.277487$	
Solving for b_1				$b_1 = -0.657496$	
Check by substituting in Eq. 10:		$1.72(-0.657496)+2.18(1.340754)+1.81(-1.846381)$		$= -1.55$	
				$1.540999 = 1.55$	

Then:

$$b_1 = -0.6575$$
$$b_2 = 1.3408$$
$$b_3 = -1.8464$$
$$R^2 = \frac{b_1\Sigma YX_1 + b_2\Sigma YX_2 + b_3\Sigma YX_3}{Y^2}$$
$$= \frac{(-.6475)(-0.53) + (1.3408)(-0.20) + (1.8464)(-1.55)}{4.28}$$
$$= \frac{0.3485 - 0.2682 + 2.8619}{4.28} = \frac{2.9422}{4.28} = 0.687430$$
$$R = \sqrt{.687430} = 0.83$$
$$a = \bar{Y} - b_1\bar{X}_1 - b_2X_2 - b_3\bar{X}_3$$
$$= 3.73 - (-0.6575)(6.33) - (1.3408)(27.43) - (-1.8464)(4.51)$$
$$= 3.73 + 4.1620 - 36.7781 + 8.3273$$
$$= -36.7781 + 16.2193 = 20.5588$$

Sample Calculation

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3$$
$$= -20.5588 - (-0.6575)(6.0) + (1.3408)(26.8) + (-1.8464)(4.55)$$
$$= -20.5588 - 3.9450 + 35.9334 - 8.4011$$
$$= 3.0285$$

Similar calculations were undertaken to determine the coefficients for (a) four samples, (b) five samples, (c) six selected observations, and (d) three selected samples. The coefficients determined were:

Sampling	Coefficients			R	a	Y (Sample Calculation)
	b_1	b_2	b_3			
Three samples	−0.6575	1.3408	−1.8464	0.83	20.5588	3.0285
Four samples	3.5365	−0.3363	−3.9381	1.01	8.3682	2.6560
Five samples	2.8855	−0.2123	−3.2439	0.96	5.9530	2.8167
Six selected observations	0.2287	0.1622	0.0923	0.96	0.1216	8.1706
Three selected samples	0.7652	−0.6502	−0.0237	1.00	17.0345	3.7118

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UTILIZATION OF SEWAGE SLUDGE FOR THE PRODUCTION OF TOPSOIL *

BY ARTHUR J. SCANLON

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In New York City, the idea of recovering organic sewage solids and returning them to the soil as fertilizer has been advocated since the early screening plants were built in Brooklyn and Queens. No significant progress was made in this direction until 1935, when the practice of separate sludge digestion was established at the Coney Island sewage treatment plant. Digestion not only produces an odorless sludge acceptable as a fertilizer or soil conditioner, but also yields a valuable product in the form of methane gas which is used for heat and power.

Topsoil Building

The first digested sludge from the Coney Island plant was used in 1936 on the plant grounds to stabilize the existing sand cover and produce a topsoil for lawn making. In December of that year, a barge load of digested sludge was taken about a mile to the proposed Marine Park recreational site, an area of approximately 725 acres, adjacent to Floyd Bennett Airport near the south end of Flatbush Ave. Approximately one-fourth of the area was suitable for the air drying of wet sludge. The remainder of the area was marginal and was to be used for a landfill operation.

The original Coney Island plant included facilities for dewatering the digested sludge by a vacuum filter with the thought that the sludge could be used as a fertilizer. However, operation of the vacuum filter was more costly than the air drying of sludge at Marine Park, and the filter operation was discontinued.

The New York City park and sanitation departments instituted an extensive sanitary landfill program for reclaiming marginal lands throughout the city. The final development of the landfill areas for recreational purposes depended on the securing, at reasonable cost, the topsoil required to sustain lawns, shrubs, and trees.

Two million cubic yards of topsoil were needed for covering 1,900 proposed acres throughout the city. This quantity of topsoil was not available within the city or in neighboring counties. The New York City Park Department, therefore, retained a landscape architect as a consultant to report on economical ways and means of making topsoil artificially. His investigation was not limited to the utilization of sewage sludge alone but included studies of other methods which might be successful in producing a topsoil. The consultant found that at

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Spring Creek Park, Queens; Marine Park, Brooklyn; and Great Kills Park, Staten Island, which have hydraulically pumped sand coverings, artificial topsoil could be created economically through the use of sewage sludge. These three sites comprised 1,400 acres of the 1,900 potential acres of reclaimed lands proposed for parks.

As a result of these studies, the Park Department consultant estimated that the artificial topsoil could be produced in place at a cost of $1,600 per acre by using sludge, as compared to $4,500 per acre for the buying and placing of natural topsoil. However, no allowance was made by the consultant for the delivery of the sludge to the park areas by the Department of Public Works, a cost chargeable to sewage disposal operations. The Department of Parks approved the recommendations of the consultant and in 1950 requested funds to initiate the program at Marine Park. The Department of Public Works asked that the program of sludge disposal in park areas be arranged so that it would not interfere with the disposal of sludge from the nine plants being serviced by the sludge vessels.

The operation at Marine Park has proven most satisfactory as far as cost, adequacy, and noninterference with sludge disposal at sea are concerned. The program has provided New York City with (a) a cheap method of disposing of digested sludge and, (b) a suitable, inexpensive topsoil from the organics in the sludge.

At Marine Park, a sludge pumping station was constructed on an abandoned dock in Mill Basin. Four positive displacement 350 g.p.m. pumps are housed in the pumping station. The six cargo tanks on the sludge vessel (Figture 1) are dewatered in 4 to 5 hr. through the use of flexible 6-in. hoses and aluminum deck and drop pipes. The dock site is separated from the

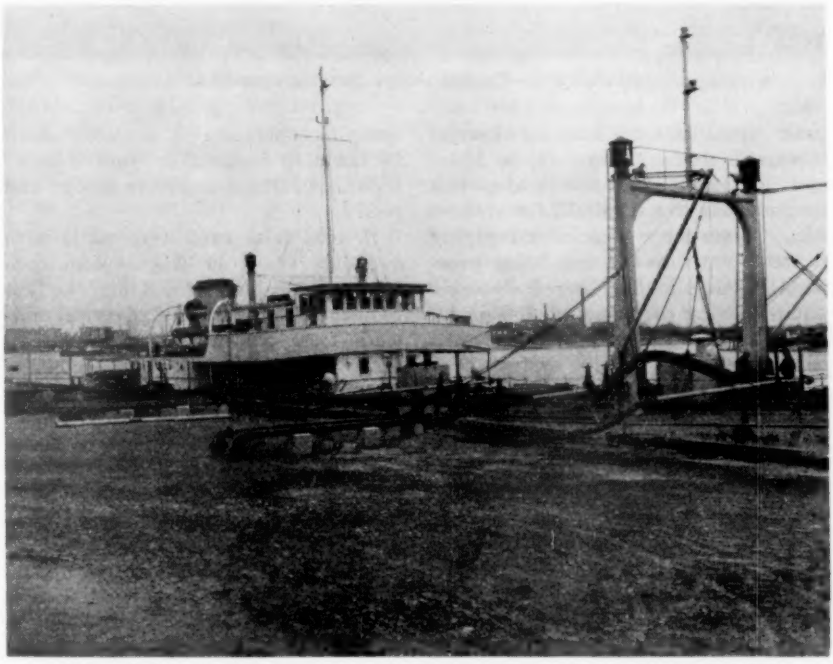

FIGURE 1.—Sludge vessel unloading wet sludge at the Marine Park dock.

FIGURE 2.—Typical sludge spraying operation.

park by Flatbush Ave., a heavily traversed road. Therefore, a 12-in. cast iron pipe was laid under this thoroughfare to a manifold from which 6-in. diameter aluminum piping stretches out into the area being processed. Gasoline powered booster pumps having capacities of 400 g.p.m. at 75 p.s.i., were installed at critical points in the distribution system.

An area of approximately 40 acres is processed at one time. The sludge is sprayed through a 1½-in. diameter fire department deck-type nozzle (Figure 2). Each sprayer can apply the wet sludge at the rate of approximately 1 gal. per square foot over an area 80 ft. in diameter. The sludge is allowed to dry for two or three days after which it is disked into the upper 9 in. of sand cover. The sludge spraying operation is repeated about 16 times to an area or until 4-in. of topsoil is formed from the sludge and sand.

Several trial runs were made with a sludge vessel in August and September, 1955. In late October, the first regular trip of a sludge vessel was made from the Jamaica sewage treatment plant, along the south channel of Jamaica Bay and then north into Mill Basin, to the new pumping station, a distance of 9.8 nautical miles. This compares with a distance of 22.2 nautical miles to the sludge dumping grounds in the Atlantic Ocean. Normally a trip to and from the dumping grounds from the Jamaica Bay plant takes about 5 hr., whereas a trip to and from Mill Basin takes about 8 hr., 3 hr. for traveling and 5 hr. for

dewatering. However, in Jamaica Bay, vessels do not operate at night because the channels used are not lighted. A simple solution to the problem of longer trips to Mill Basin was to schedule the vessels to permit unloading by Park Department personnel in the late evening when the marine personnel were not on board. Thus the advantage of the shorter haul was obtained, and the vessels were available for more trips than in previous years.

In 1955, 18 sludge vessel trips were made to Mill Basin for sludge unloading. During 1956 a total of 110 trips were made. Better than 95 per cent of these trips were from the Jamaica and Rockaway plants; these plants have the shortest running time to Mill Basin. On a quantity basis, the volume disposed on land areas in this operation was more than 3,500,000 cu. ft.

Sludge Bed Facilities

In the operation of the sludge barges from the Coney Island plant, sludge pumping facilities had always been provided on the barge and the existing dock was suitable for continued removals. The gasoline booster pumps were available for spraying in any area. Thus the removal of sludge from the Coney Island plant conveniently fitted into the expanded plans for the utilization of sludge in the preparation of topsoil. During 1956, 175 barge trips, carrying about 1,500,000 cu. ft. of wet sludge, were unloaded at Marine Park. The digested sludge was sprayed rather than pumped into drying beds as was done in previous years. In three different sludge bed areas located in the southwest, northeast, and southeast areas of the proposed park some 35,000,000 cu. ft. of wet sludge was dried between 1936 and 1955.

During 1956, all the sludge was removed and placed on graded areas and disked into the sand cover to form topsoil. Most of the dried sludge was used on areas adjacent to avenues or highways where the spraying of sludge would be undesirable. On the easterly border of Marine Park an extensive strip adjacent to the avenue has been planted to grass, using the sludge from the first beds which were active up until 1948. On the north side of the Belt Parkway, which runs through Marine Park, the sludge from the last beds is being disked into the sand cover in preparation for grass seeding.

In 1956, 5,000,000 cu. ft. of sludge were sprayed on landfill areas. There are large areas that have been land filled and are ready for top dressing, and also other large areas which require landfill before top dressing can be added. This program will require many years and millions of cubic feet of sludge to complete.

Canarsie Pol

During 1956, another means for the disposing of sludge was provided and placed in operation at the 26th Ward plant. A 12-in. pipe line, submerged from the end of the sludge vessel loading line at the dock, was placed 6,000 ft. across the North Channel of Jamaica Bay to a high area known as Canarsie Pol. Canarsie Pol is a sandy barren area of about 250 acres, about 8 to 10 ft. above mean sea level. Access to the Pol is limited to very shallow draft vessels and then only at high water.

Conservationists of the United States Fish and Wildlife Service and the New York State Conservation Department were most desirous of developing this island for a bird sanctuary. Organic material was needed to sustain vegetation for feeding and sheltering the birds. Therefore, plans were made for the installation of a high-pressure pump and a pipe line to carry the sludge from the 26th Ward plant to the Pol.

The design and construction of this installation were carried out under the jurisdiction of the Department of Parks. The first sludge pumping op-

eration was undertaken in December, 1955. The cost of the pump and pipe line was charged to the development of the bird sanctuary. This provided the 26th Ward plant with a third method of sludge disposal. The other two methods were a dock with facilities for loading the sludge vessels and eight acres of sludge drying beds at the south end of the plant. Normally the beds could not satisfy the total requirements of the plant and sludge vessels were required to assist in the removal of sludge.

During 1956, sludge vessels were not required. About one-half of the sludge removed from this plant (1,500,000 cu. ft.) was disposed of via the pipe line. This amount would have been greater were it not for pipe blockages and breakages during the year.

One very novel development in the operation at Canarsie Pol was the use of a helicopter. Because of the inaccessibility of the Pol, there were many days that the amount of sludge in the different lagoon areas could not be determined and additional pumping might have caused spilling of sludge over the lagoon berms into the waters of Jamaica Bay. The helicopter patrol of the New York City Police Department was requested on several occasions to report the situation on the Pol. Pumping operations were varied accordingly.

At the present time, there is a stockpile of about 10,000 cu. yd. of dried sludge removed from the 26th Ward sludge beds. All of this material will be transported to Marine Park where it will be used as topsoil for the border area adjacent to avenues and highways in much the same manner as the dried sludge from the beds at Marine Park. In previous years, the dried sludge at the 26th Ward plant was a source of supply of topsoil for landscaping projects of the Park Department and for use by the Department of Public Works for the landscaping of the Owls Head and the 26th Ward plants.

Cost of Operations

Robert F. Moses, Commissioner of Parks, has stated that natural topsoil for city parks would cost about $3.50 per cubic yard. However, the "ersatz topsoil" from digested sludge can be produced for $1.50 per yard. This difference means millions in the taxpayers' pockets, a matter of simple arithmetic.

The cost of $1.50 per cubic yard for making the ersatz topsoil does not include any charge for the transportation of the sludge to the dock or park area. As stated previously, disposal of sludge is normally charged to the sewage treatment operation. If the cost of transportation to the proposed park areas is less than the normal cost of sludge disposal at sea, then the city realizes an added saving. On the other hand, if this cost is more than the normal disposal cost, then an additional charge should be made for the ersatz topsoil.

In the analysis of whether there is any saving or an extra expense in making synthetic topsoil against buying topsoil, a comparison can be made with the normal cost of sludge disposal by vessels at sea. For the three-year period, 1953 to 1955, the cost of maintenance and operation of the four sludge vessels serving 9 sewage treatment plants, together with the fixed charges, was $0.43 per wet ton and $9.31 per dry ton. Of this amount, maintenance and operation charges were $0.35 per wet ton and $7.60 per dry ton, respectively.

In the operation of the sludge vessels to the Marine Park dock, the trips required only one-half the mileage of those to sea. The services of the boat personnel were reduced further by the fact that unloading at Marine Park was restricted to the evening hours without the use of marine crews. Therefore, there was a saving of fuel oil consumption, wear on the propulsion engines, and personnel charges.

This saving is estimated to be about 10 per cent of the cost of dumping the sludge at sea.

Pumping from the 26th Ward plant to the Canarsie Pol is a negligible additional operating cost since pumping has to be done in any event either to the beds or to sludge vessels. The fixed charges for the pump and pipe line are estimated at $0.12 per wet ton. While these fixed charges are $0.04 per wet ton more than the fixed charges for the sludge vessels, the operating and maintenance charges are negligible as compared to the cost of $0.35 per wet ton in the case of the vessels. With this appreciable saving, the cost of sludge disposal from the 26th Ward plant to the Canarsie Pol is about one-quarter of the cost of sludge disposal using vessels.

In 1956, sludge barge operations from the Coney Island plant were not significantly different from the operations carried out for the past 20 years. However, the sludge force main to Canarsie Pol and the delivery of sludge to Marine Park by sludge vessels are two new methods of sludge disposal introduced in the past two years.

The cost of these two new methods is approximately 25 per cent less than the normal cost of sludge disposal at sea. This saving may be added to the $2.00 per yard saved using sludge for topsoil. The total saving realized by the city through this operation is about $2.50 per yard. With the expected use of approximately 400,000 cu. yd. of ersatz topsoil in Marine Park the saving to the city as compared with natural topsoil will approach the $1,000,000 mark.

The final criterion of an efficient operation of this process is to have no interference with the conventional disposal of sludge to sea. This criterion too, is more than met. In 1956 the sludge vessels made a total of 1,250 trips, more trips than were made in any previous year since the last four treatment plants were placed in operation in 1952. As a matter of fact, there was a 10 per cent increase in 1956 in the number of trips and the amount of sludge carried compared to 1955.

Future Developments

The process of obtaining topsoil from sludge at Marine Park during 1956 was a success. The program will continue at this park, and expanded facilities for sludge utilization are planned at Great Kills Park, Staten Island, and Spring Creek Park, Queens.

The installation for the Great Kills project, which covers an area of 500 acres, will differ from Marine Park in that the centrifugal pumps will be mounted on the sludge vessels instead of being housed in a separate building on the shore as at Marine Park. This will be done to speed up the sludge unloading time since layovers at this location will be impracticable.

Spring Creek Park covers an area of 180 acres and is approximately 9,000 ft. from the Jamaica plant dock where the sludge storage tank is located. A pump will be installed at this site with a force main to the park area.

Experience has shown that where distances are not excessive, pumps and pipe lines are the most economical method of transporting sludge.

Summary

A new method of sludge disposal, supplementing disposal at sea, is now being employed by the City of New York. The Department of Public Works transports digested sludge to proposed park sites. The Park Department removes the sludge from the boats and produces artificial topsoil at the sites.

The city realizes a substantial saving by creating this artificial topsoil. This saving is twofold: (a) transportation charges to the park site are less than sea disposal charges, and (b)

handling and processing charges at the park sites are much less than the cost of natural topsoil.

Aside from these tangible savings, the most important consideration is that the digested sludge used in making ersatz topsoil provides the solution to the problem of obtaining natural topsoil which is not available in large quantities locally.

VACUUM SLUDGE FILTRATION EXPERIENCES *

I. HARTFORD, CONNECTICUT

By Karl H. Baron

Supervisor of Digestion and Filtration, Hartford Sewage Treatment Plant, Hartford, Conn.

The Hartford, Conn., sewage treatment plant is of the primary sedimentation type and treats a combined sanitary and storm flow. Designed for an average dry weather flow of 39 m.g.d. and a maximum flow of 80 m.g.d., operation was started in 1938. There are four fixed cover primary digesters, 50 ft. in diameter and 30 ft. deep. Two 8-ft. by 14-ft. vacuum filters and auxiliary equipment for elutriation are provided for dewatering digested sludge. The digested sludge contains 3 to 4 per cent dry solids and is drawn to the elutriation tanks six days a week at a rate of 120 g.p.m. for 6 hr. each day.

Filter Operation

Elutriation

The Genter countercurrent system of elutriation is the method used in washing the sludge prior to filtering. Two mixing tanks and two settling tanks are used in such a manner that the sludge receives two washings with the same volume of water. Elutriating water is obtained from 36 wellpoints driven down to coarse gravel in an area adjacent to the filter house. On the days that digested sludge is drawn but not filtered, single-stage elutriation is used, but when the filters are operated the countercurrent system is operated to keep up a continuous and fairly constant supply of sludge to the filters.

The rates of flow of sludge and water through the elutriation system is automatically controlled by means of flowmeters and motor operated valves. Elutriation reduces the alkalinity of the sludge from approximately 2,700 p.p.m. to approximately 225 p.p.m., so that the use of lime is not necessary for conditioning the sludge prior to filtering. After the second washing the sludge is pumped to the sludge feed tanks, then moved into the conditioning trough by means of paddle wheels which control the rate of flow into the trough.

Filtration

Each conditioning trough is 20 ft. long, 2.5 ft. wide, and 3.5 ft. deep. Experience has indicated that the detention time of the conditioned sludge can be reduced considerably by placing a weir in the trough just before the point of ferric chloride addition, thus shortening the effective length of the trough by 12 ft.

A dipper-type ferric chloride feeder is mechanically connected to the sludge feed wheel drive so that the addition of the ferric chloride is in proportion to the speed of the feed wheel. Mixing of ferric chloride and sludge in each

* Presented at the 1957 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 17–18, 1957.

trough is accomplished with four oscillating paddles. The conditioned sludge flows through an inverted siphon to the center of the bottom of each filter vat.

The inverted siphon places a limit on the solids content of sludge that will flow to the filter. A sludge with 6 per cent or less solids will go through without difficulty, but if a heavier sludge, 10 or 11 per cent solids, appears in the feed tank, water must be added to thin the sludge sufficiently so that it will flow through the pipe. Heavy sludge requires more ferric chloride for conditioning and, since the filter has to be slowed down, it has been found that the production of dry solids after a day's run is no greater. In addition, more ferric chloride is used than with a sludge having 6 per cent solids.

Each vacuum filter is operated as a unit with its sludge pump, feed wheel, and conditioning trough. The vacuum pumps and air blowers are common to both filters.

The average vacuum on the filters is about 22 in. and the air pressure on the blow is 2.5 p.s.i. The blow pressure can be adjusted to a maximum of 3 p.s.i. but experience indicates that 2.5 p.s.i. is optimum. The thickness of the sludge cake depends on the solids content of the sludge, the chemical dosage, and the speed of drum rotation. The cake thickness varies from $\frac{1}{8}$ to $\frac{3}{8}$ in. with a drum speed of $\frac{1}{2}$ r.p.m. The production rate at this speed averages 6.39 lb. per square foot per hour. The average pH is 6.2 and the per cent ferric chloride is 1.83 on a yearly basis. The average production of cake per 6-hr. day is 38 tons at 68 per cent moisture.

Filter Cloths

Wool filter cloths have been used most of the time, but a pounded felt cloth was tried and at present 100 per cent Dacron fabric is on the drums to determine how it compares with wool.

The average life of wool cloths is about 800 hr., the two felt cloths each gave about 250 hr. of service, then became so thin that numerous small holes appeared and it was evident that the cloth would soon tear badly if not removed. One Dacron cloth has been on the drum for about 200 hr. and is in better condition than the wool cloths were after the same period of operation. The Dacron cloths respond more readily to cleaning with the filter spray than other cloths.

When a filter cloth is so badly blinded that the filter spray will not clean out the sludge, a single high-pressure stream from a $\frac{1}{4}$-in. nozzle is used to penetrate to the back of the cloth and drive out the sludge. This is a time-consuming job but it does clean the cloth. Output is considered satisfactory if a reasonably good cake is produced on approximately 75 per cent of the drum area, even though the cloth is partially blinded.

Recently a detergent * has been used to first soften the sludge, followed by cleaning with a high-pressure stream of water. The filter vat is washed out as much as possible with water, then filled with approximately 300 gal. of water and 3 qt. of detergent. The filter agitator is operated and the drum is run at full speed with the air blow on for a minimum of 4 hr. before draining the vat and washing with water. This procedure usually removes most of the cloth blinding.

Control

The control of the filtering operation becomes largely automatic after the initial start. The level of sludge in the feed tank is maintained by a level indicator that also controls the speed of the sludge pump. The feed wheel maintains a constant level in the

* Ultrawet 60L, Atlantic Refining Company.

conditioning trough by a similar control, and the chemical feeder follows the speed of the feed wheel.

An electrical control board is located adjacent to the filters and in addition to control switches has level indicators, pressure and vacuum gauges, and indicators showing "gallons per minute" of sludge going into the conditioning trough. The operator, by observing the rate of flow indicator to the conditioning trough, can detect whether the sludge is thickening or thinning, or if a liquid level float wire has broken or mechanical trouble has occurred in the chemical feeder, pump speed controls, etc.

There have been practically no repairs required on either of the filters up to 1956. Every other year the rotary valve is removed and the surface of the valve wearplate is ground or refaced in a lathe, if necessary, and then hand ground to a smooth surface on both plate and valve body.

When a new filter cloth is required, the old cloth is removed and the monel screens are thoroughly wire brushed to remove as much sludge as possible before the new blanket is installed. It usually takes four men about 2½ days to change both cloths.

Early in 1956 the staves on the drum of one of the filters became so badly rotted that it was necessary to operate at a much lower vacuum in order to avoid enlarging the holes. New material was ordered and after about five weeks of work the filter was as good as new. The job took longer than was expected because two special A-frames had to be fabricated to support a steel wire exactly over the longitudinal center of the drum to aid in aligning the staves and interior piping connections. Special tools were obtained from the filter manufacturer for boring holes for drum nozzles, and turning a true surface on the drum. A service engineer supervised and assisted in the repair which certainly was of a specialized nature requiring expert assistance. The other filter is to be restaved.

The two filters have given about 18 years of dependable service with a minimum of repairs. Regular lubrication and painting is good preventive maintenance, and has contributed to the life of this equipment.

II. EAST HARTFORD, CONNECTICUT

By E. A. Locke *

Engineer, Sewage Treatment Plants and Pumping Stations, Hartford, Conn.

The East Hartford, Conn., sewage treatment plant was built during 1953–54 and went into operation in April, 1954. The plant has a design dry weather flow of 4 m.g.d. and a maximum flow of 10 m.g.d. The present flow is about 2.7 m.g.d. Sewage receives primary treatment only and the effluent is discharged to the Hockanum River. Equipment consists of a bar screen, grit chambers, comminutors, electric and gas driven sewage pumps, covered sedimentation tanks, sludge pumps, primary and secondary digesters, an elutriation tank, and two vacuum filters.

Digested sludge is drawn to an elutriation tank 20 ft. in diameter, 10 ft. deep, equipped with a picket-type stirring mechanism. The elutriate can be returned to the sedimentation tanks or discharged to the plant outfall.

The sludge is drawn from the secondary digester, usually for about 45 min. The elutriation sludge pump is operated at a rate of 40 g.p.m. and the elutriation water pump is set for 100 g.p.m., thereby giving an elutriation ratio of 2½ to 1. Plant effluent

* Retired, May, 1957.

is used for the sludge washing and the alkalinity is reduced from approximately 2,000 p.p.m. to approximately 400 p.p.m. or about 80 per cent reduction. Elutriation usually takes about 12 hr.

The operation of drawing and elutriating the sludge is usually repeated three or four times in order to obtain enough sludge to supply the vacuum filters for one day of operation. It has been found that too many of the fine solids are washed out of the sludge if too much digested sludge is drawn at one time. Furthermore, the gas pressure is reduced to a point where the gas engine pump does not operate properly. Another difficulty is that considerable cutting oil and laundry wastes are at times received with the sewage and they tend to prevent ready settling of sludge; hence elutriation is at a rather slow rate.

The sludge filtering equipment consists of two package-type vacuum filters, 5 ft. in diameter by 6 ft. in length. They are located end to end with the sludge conditioning equipment between the adjacent ends. The sludge cake is discharged onto a belt conveyor which deposits the cake in a storage hopper in the floor. The sludge can be discharged from the hopper into a truck located on the lower floor. The filter drum and filter agitator are driven by variable speed motors; the wet vacuum pump, air compressor, and filtrate pump are operated by one large motor. Elutriated sludge is pumped to the conditioning trough by a variable speed plunger pump. Excess sludge flows over a weir and is returned to the elutriation tank.

Ferric chloride is diluted with water just before entering the conditioning trough to produce a more thorough contact with the sludge. A small picket-type mixer with a variable speed motor drive provides good mixing of ferric chloride and sludge.

The conditioned sludge flows by gravity into either one or both of the filter vats. The elevation of the sludge in the vat is maintained by the position of the overflow weir at the conditioning trough, and it is kept at a level that submerges one-quarter to one-third of the filter drum. The sludge detention time is short because of the short distance between the conditioning trough and the filter vat. The equipment and its arrangement makes it possible to handle elutriated sludge with 12 per cent solids without difficulty.

With the present digester loading, it is only necessary to operate the filters for one 6-hr. run about three times per month. The drum turns about one revolution in 3 min., and produces a cake thickness of approximately 3/16 in. with approximately 34 per cent dry solids, at a production rate of 6.5 lb. per square foot per hour, with about 2 per cent ferric chloride. A record run produced 9.52 lb. of dry solids per square foot with 1.06 per cent ferric chloride.

Operation

One of the problems in operating vacuum filters is to avoid having too much water discharged with the cake. Usually this is the result of (a) too much vacuum caused by an impervious cake, (b) too high drum speed, (c) too low chemical dosage, or (d) the presence of too much oil or grease in the elutriated sludge. It has been the practice at East Hartford, when too much water is coming off with the sludge cake, to slow down the drum and, if necessary, to increase the chemical dosage. The filtrate is tested for pH every 30 min. and the chemical feed is readjusted if necessary. The optimum pH is usually around 6.2. A poor cake will start to blind at the division strips and this gradually spreads over the sections unless the trouble is corrected.

After the filters have been started and are producing cake, the agitator is operated only when there is evidence that wet cake is being rubbed off by

a pile-up of sludge between the rear wall of the vat and the drum, as the drum emerges from the liquid. The agitator is then operated until no ridges of sludge are visible on the drum.

Wool cloths were installed on the filters initially, but the life seemed rather short, about 275 hr. A Saran fabric, No. 900, which is a screen type of monofilament weave, with about 1,000 openings per square inch, is being used on one of the two filters. The Saran cloth is operated with a lower vacuum (16 in.) and gives good production with good sludge. It seems to discharge more water with the cake if there is considerable oil in the sludge or a higher vacuum is used. When this occurs it becomes necessary to slow down the drum speed.

It is customary to run both filters and, therefore, the same conditioned sludge goes to both vats. If it were possible to condition the sludge for each filter separately, probably a different ferric chloride dosage for each type of cloth would produce more cake.

The Saran cloth is easily cleaned with the spray so if blinding occurs during a filter run, the next run can be started with a clean drum surface.

The wool cloth is operated at 22 in. of vacuum and gives a much clearer filtrate, about 66 p.p.m. suspended solids; whereas the Saran cloth with the open mesh allows much more sludge to pass through, giving a filtrate of about 1,500 p.p.m. suspended solids. The filtrate is returned to the elutriation tank and may pass through the filter cycle again; however, this is of minor importance if the cloth has a long life. The present Saran cloth has been in use for more than 250 hr. and shows no sign of deterioration.

The East Hartford plant was designed to use plant effluent in the wash water system. This has caused occasional difficulty with clogged screens and sticky solenoid valves on the line feeding the seals on the vacuum and filtrate pumps. The use of clear water would probably prevent these troubles.

A major difficulty has been with the ferric chloride supply to the feeder. The chemical is mixed in an open tank and pumped up to the feeder tank. The pump was constructed of a metal alloy that was expected to resist the corrosive action of ferric chloride, but failed to do so. Eventually the pump had to be replaced with a hard rubber pump.

The two filters have been in operation for more than two years, have required no repairs, and have given excellent service. The digested sludge has been rather difficult to filter at times, due to industrial wastes rather than to any fault of the filters. If the wood staves on the drums last as well as at the Hartford plant, it is expected that the filters will provide many years of operation before major repairs will be necessary.

III.—GOWANDA STATE HOSPITAL, GOWANDA, NEW YORK

By W. L. Edwards

Plant Operator, Gowanda State Hospital, Gowanda, N. Y.

Although the vacuum filter at the Gowanda State Hospital, Gowanda, N. Y., has a filtering area of only 54 sq. ft., it has presented operating problems similar to those encountered with larger units. The unit is used to filter a heavy, thick black digested sludge. Approximately 3,200 gal. of sludge could be filtered during a 6-hr. operating day. However, the solids content increased through the conditioning tanks to the point where the flow

was not sufficient to keep the filter vat supplied.

The raw sludge is conditioned with 20 per cent ferric chloride in the first conditioning tank of the rotary vacuum filter. It becomes so heavy and thick that water must be added to keep the sludge moving through the second conditioning tank. Lime is added in the third conditioning tank and the sludge is agitated with air before flowing to the filter bucket elevators.

The thick conditioned sludge would not flow properly for continuous filter operation. After two or three stops, the filter cloth would become so blinded that a good cake could not be obtained until the filter was washed. The washing operations required about 1½ hr., thus cutting the effective filtering time to 4½ hr. Increasing the quantity of water added to the raw sludge made it flow better, but required the use of more ferric chloride.

Considerable experimental operation, with an accompanying waste of time and chemicals, was necessary before satisfactory sludge filtering could be accomplished. Sufficient water was added to the first conditioning tank to maintain flow through the stages of adding ferric chloride and lime, and mixing. As the thick conditioned sludge discharged from the filter elevator, a stream of water was introduced to thin the sludge to a consistency whereby the proper level could be maintained in the filter vat. This addition of water eliminated the

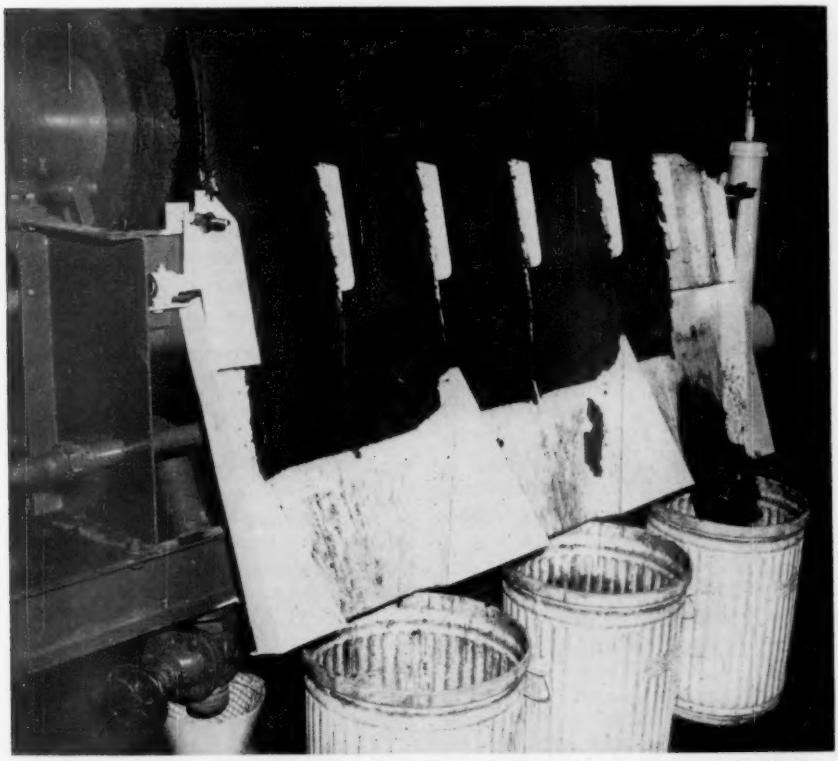

FIGURE 1.—Small vacuum sludge filter, Gowanda State Hospital, Gowanda, N. Y.

trouble caused by the sludge forming a plug in the 3-in. pipe from the elevator to the filter vat.

Unfortunately, the filter cloth continued to blind after 2 to 3 hr. of filtration. At this time the conditioning chemicals were changed to the use of unslaked ground lime, in lieu of the chemical lime, and 12 to 14 per cent ferric chloride. The addition of water at the filter elevator was continued, whereas water was no longer added in the first conditioning tank. Following this change the filter operated 6 hr. per day without blinding and 3,700 to 4,100 gal. of sludge could be filtered.

The dried sludge is collected in cans (Figure 1) and weighed. Previously a good day's run resulted in the production of 80 cans of sludge cake, which weighed about 125 lb. each (5 tons wet sludge). Now 100 to 125 cans of cake can be collected for an increase of 2 tons of sludge per day. The cake on the filter averages 3/8 in. during the entire filter run.

As a result of the changes in chemicals and the addition of water, considerable quantities of chemicals and water are saved. The production of filter cake has increased and more effective operation has been achieved.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"Worry kills energy, purpose, vitality—and produces nothing."—*Anon.*

Attention operators! It will be appreciated if copies of the annual reports of both large and small sewage and industrial waste treatment plants are sent to the Federation office for abstracting in this section of the Journal. Please direct annual reports to: The Operator's Corner, SEWAGE AND INDUSTRIAL WASTES, 4435 Wisconsin Ave., N.W., Washington 16, D. C.

Operation Report of the Marion, Ind., Sewage Treatment Plant for the Years 1955 and 1956 *

BY GORDON L. WATSON, *Superintendent*

In January, 1956, Gordon L. Watson succeeded E. S. Savage as superintendent of the water and sanitation departments. The sanitation department is responsible for garbage and refuse collection and the operation of the sewage treatment works. The green garbage is hauled to the treatment plant, where it is ground and pumped directly into the digesters.

The year 1957 marks the 80th anniversary of the Marion water department as a city-owned and operated utility.

The several gas engines which drive the air compressors for the activated sludge units were dismantled and overhauled as needed. Other units requiring periodic overhauling were the air compressors and the comminutor. Routine inspection and maintenance kept the plant operating at top efficiency.

The roof of the No. 1 digester was replaced with a prefabricated roof in 1955 and the No. 2 digester was re-

* For last previous extract see THIS JOURNAL, **25**, 8, 975 (Aug., 1953).

TABLE I.—Summary of Operating Data at Marion, Ind., for the Years 1955 and 1956

Item	Average 1955	1956
Rainfall (in.)	34.71	29.47
Tributary population-equivalent:		
Susp. solids (0.22 lb. per cap.)	56,400	—
B.O.D. (0.17 lb. per cap.)	24,800	31,200
Sewage flow (m.g.d.)	5.9	5.4
Suspended solids (p.p.m.):		
Raw	221	320
Settled	87	108
Final	13	13
Removal (%)	93.0	93.7
B.O.D. (p.p.m.):		
Raw	87	113
Settled	74	84
Final	6	3.5
Removal (%)	93.4	96.8
Activated sludge:		
Ratio returned sludge to flow (%)	30.1	35.3
Detention in aeration tanks (hr.)	3.80	3.77
Mixed liquor susp. sol. (p.p.m.)	2,776	3,530
Returned sludge susp. sol. (p.p.m.)	11,519	12,678
Returned sludge, per cent volatile	54.0	54.0
Sludge index (Mohlman)	70	52
Cu. ft. air per gal. raw sewage	0.78	0.92
Cu. ft. air per lb. B.O.D. removed	1,637	1,313
Raw sludge data:		
Dry solids (1,000 lb. per month)	427.1	549.3
Total solids (%)	6.16	7.45
Volatile solids (%)	42.9	42.6
Digested sludge data:		
Wet solids removed (1,000 gal. per month)	530.3	485.6
Dry solids removed (1,000 lb. per month)	304.6	336.4
Total solids (%)	7.78	9.61
Volatile solids (%)	32.8	34.0
Garbage disposal:		
Green garbage hauled to plant (1,000 lb. per month)	4,476.7	4,384.8
Dry garbage solids to digester (1,000 lb. per month)	64.9	73.9
Volatile solids (1,000 lb. per month)	57.2	62.2
Digester gas:		
Cu. ft. per lb. volatile solids	8.87	7.78

roofed in 1956. Approximately 70 per cent of the plant power requirements is furnished by the digester gas.

During 1955 the worn shoes on the primary tank collectors were reversed for additional service. A new plant intercommunication system was installed.

A tornado struck Marion on the night of March 6, causing extensive damage, but costing only one life. All garbage crews were called out to aid in street cleanup.

Sewage treatment plant operating personnel were encouraged to attend professional meetings and short courses when available. Occasional in-plant gatherings of the staff for discussion of operational problems have proven of interest.

Particular attention was given to keeping the plant grounds attractive, with flower plantings and adequate lawn care. The entire park area at the plant was cleared of fallen trees and trash.

A summary of operating data for 1955 and 1956 is given in Table I.

CAN YOU IDENTIFY PUMP CORROSION?*

Occasionally pump parts fail after a very short length of service, due to corrosion. Pump parts may also fail prematurely because of erosion. In either case a change in metals is indicated. In order to avoid expensive trial and error solutions it is necessary to determine whether the part failed due to corrosion, erosion, or possibly a combination of the two. "Hit or miss" selections are costly. Considerable savings can be made by correct identification of the nature of the failure. This paper presents some information on different types of corrosion and how they can be readily identified.

Corrosion is defined simply as the destruction or deterioration of metal by electrochemical reaction. True corrosion can be grouped into a few basic types which are quite easily identified, as follows:

Corrosion	Identification
Galvanic	Localized deep grooves or pits, usually at contact of two dissimilar metals.
Uniform	Uniform attack or corrosion —may be on only one part.
Intergranular	Attack at the grain boundaries.
Pitting	Frequently rapid and deep pitting at several small areas. May be quite uniform or highly localized.

In addition to various types of pure corrosion, combined corrosion and erosion may also occur. As an example, most neutral and alkaline waters cause a rust or oxide film formation on iron. This film protects the iron underneath against further corrosion. However, if erosion occurs due to high velocities in the impeller or the presence of air or vapor, the rust film is removed, leaving bare metal in contact with the liquid. Constant rusting and erosion soon result in deep grooves and perhaps complete destruction of the metal.

To determine correctly the type of attack on a damaged pump part, it is necessary to inspect all surfaces carefully. The casing and suction cover should be inspected for metal deterioration in the areas of both high velocity and low velocity. The location of greatest corrosion should be noted carefully, particularly with respect to the point of contact with dissimilar materials. The impeller should be inspected carefully on the inside and outside.

The presence of pitting on impellers does not necessarily indicate corrosion. Pitting could occur on the impeller vanes as a result of cavitation or excessive air. However, if corrosion pitting has occurred, it generally will be in evidence not only on the impeller vanes but also on the underside of the vanes and on the outside of the impeller shrouds. If only cavitation is present, pitting will be localized on the working side of the impeller vanes.

* *Goulds News*, Goulds Pumps, Inc., Seneca Falls, N. Y.

HATFIELD AWARDS

The 1957 William D. Hatfield Award competition is nearing a close for the 18 Member Associations eligible to name a recipient this year (THIS JOURNAL, **29**, 1, 110; Jan., 1957). The purpose of the award is to encourage good sewage and industrial waste treatment plant operation and to recognize the operator who does better than average. Check with your Member Association secretary for details.

TIPS AND QUIPS

Stormy Weather Safety

The National Board of Fire Underwriters recommends the following guide for personal safety during thunderstorms:

Do not go out-of-doors or remain out during thunderstorms unless it is necessary. Stay inside of a building where it is dry, preferably away from fireplaces, stoves, and other metal objects.

If there is any choice of shelter, choose in the following order:

1. Large metal or metal-frame buildings.
2. Dwellings or other buildings which are protected against lightning.
3. Large unprotected buildings.
4. Small unprotected buildings.

If remaining out-of-doors is unavoidable, keep away from small sheds and shelters if in an exposed location, isolated trees, wire fences, and hilltops.

Zimmermann Wet Combustion

The Metropolitan Sanitary District of Greater Chicago and Sterling Drug Inc. recently announced plans to undertake research into the use of the Zimmermann Process for the disposal of sewage solids. End products after the "wet combustion" of the Zimmermann Process are water and a small amount of ash. The study will evaluate the cost of "burning" sewage sludge in various concentrations of 2 to 6 per cent and more.

The Zimmermann Process has shown promise in the treatment of waste pulp liquors from the pulp and paper industry. Sterling Drug Inc., developers of the process, will construct the pilot plant and supervise its operation at no cost to the sanitary district.

Penn State Sewage Plant Research

Efforts to develop a low cost, efficient and simple scheme for the treatment of sewage (THIS JOURNAL, **29**, 4, 468; Apr., 1957) continue with the granting of $21,148 by the U. S. Public Health Service for a two-year study at Pennsylvania State University, University Park, Pa. Under the direction of Professor R. Rupert Kountz, the project's aim is to show the way for a simpler and more economical method of waste treatment by achieving total and complete purification by means of self-liquidating bacteria, thus eliminating currently used digestion and sludge-handling processes.

Safer at Work Than at Play

The chemical industry enjoys an on-the-job accident frequency rate which is less than one-third the rate for all manufacturing and far below that in the utilities field. Accordingly, it is surprising that one of the leading chemical companies found, after a three-year study of lost-time injuries of 100,000 employees, that twice as many employees were hurt while participating in sports as were injured while at work. One out of every 20 employees suffered a lost-time injury off the job.

The athletic and sports events, in order of the number of injuries suffered, were: baseball, basketball, swimming, football, skating, hunting, fishing, bowling and volley ball. Even dancing accounted for three injuries.

Chemical industry safety leaders are concerned that safety consciousness must not end with the plant whistle. The utilities workers, particularly sewage and industrial wastes personnel, have a double concern—safety both at work and play. Don't be a foul ball—work and play safely this summer.

Federation Affairs

BOSTON MEETING PLANS WELL ADVANCED

Hotel Statler, Boston, Massachusetts, will be the setting for the 30th Annual Meeting of the Federation of Sewage and Industrial Wastes Associations, October 7–10, 1957. Historical Boston, scene of the 22nd Annual Meeting in 1949, will be revisited by an expanded Federation gathering. Convention arrangements, virtually complete, are a credit to the members of the committees which plan the numerous details of the Annual Meeting. The program planned for the ladies is one that will certainly be long remembered.

The autumn season in New England makes Boston a most attractive location to combine attendance at the technical sessions with vacation plans, either before or after the meeting. Principal programmed events are scheduled in the Hotel Statler, located in downtown Boston. Presentations on sewage, industrial wastes, and water pollution problems will furnish those in attendance with new ideas and additional technical information. Exhibits will display the latest supplies and equipment for the sewage and industrial wastes field.

Committee members of the local Host Association—the New England Sewage and Industrial Wastes Association—have been hard at work on final details for the meeting, which promises to be an outstanding affair.

Local Committees

The Local Arrangements Committee, under the general chairmanship of F. L. Flood, Partner, Metcalf & Eddy, Boston, is composed of the chairmen of the following subcommittees:

Registration Committee: J. S. Bethel, Jr., Chairman; B. Mills, III, Vice-Chairman; G. C. Coogan, J. F. Flaherty, R. F. Kelsey, J. D. Marr, Jr., and R. W. Muther, Jr.

Hotel Arrangements Committee: J. C. Knox, Chairman; C. Y. Hitchcock, Jr., Vice-Chairman; J. L. Dallas, A. E. Sulesky, W. A. Healey, R. W. Thieme, and J. M. D. Suesman.

Entertainment Committee: W. D. Brenchick, Chairman; B. P. Eaton, H. D. Kilgore, Jr., E. A. Symonds, J. R. Masterson, and H. Bergman.

Ladies' Entertainment Committee: Mrs. F. L. Flood, Chairman; Mrs. C. W. Sawyer, Vice-Chairman; Mrs. R. W. Horne, Mrs. T. R. Camp, Mrs. E. B. Cobb, Mrs. E. S. Chase, Mrs. R. W. Muther, Jr., Mrs. J. B. Hanlon, Mrs. E. R. Howard, Mrs. C. A. Knapp, Mrs. W. E. Merrill, and Mrs. B. Mills, III.

Finance Committee: W. E. Merrill, Chairman; C. O. Baird, Vice-Chairman; F. L. Heaney and S. M. Hurley, Jr.

Local Host Committee: R. W. Horne, Chairman; F. M. Cahaley, Vice-Chairman; E. S. Chase, T. R. Camp, C. G. Hamann, E. L. Bond, G. M. Fair, and W. H. Brown.

Inspection Trip Committee: J. B. Hanlon, Chairman; Francis Bergin, Vice-Chairman; Dean Coburn, A. P. Fisichelli, C. V. Hickey, and J. D. McDonald.

Transportation Committee: R. S. Burlingame, Chairman; D. A. Root, Vice-Chairman; F. R. Mahoney, Jr., R. M. Power, and L. J. Tierney.

Early Registration

To help early arrivals avoid the Monday morning registration rush on October 7, the Registration Desk will be open in the mezzanine of the Hotel Statler during the afternoon of Sunday, October 6. All who arrive during this period or before are urged to take advantage of this opportunity to register early. The manufacturers' exhibits will be open on Sunday afternoon for a leisurely inspection.

Announcement to Membership

The formal announcement of the meeting was sent to all active and corporate members of the constituent associations of the Federation in July. That announcement contains further details as to technical and social programs, registration, manufacturers' exhibits, cost of the various functions, and a reservation card for hotel accommodations. Room reservations should be made directly with the headquarters hotel, Hotel Statler, Park Square at Arlington St., Boston 17, Massachusetts. Anyone desiring additional copies of the formal convention announcement or hotel reservation cards may obtain them from the headquarters office of the Federation.

News and Notes

Of Persons and Activities in the Field of Hydrowastes

W. D. "Hap" Hatfield is retiring as Superintendent of the Decatur (Ill.) Sanitary District, after 33 years of outstanding service.

Edward F. Eldridge, Director and Chief Engineer, Washington Pollution Control Commission, has been appointed as a Special Research Assistant in the Water Supply and Water Pollution Program, Pacific Northwest Office, USPHS, Portland, Ore.

The Pollution Control Council, Pacific Northwest Area, recently elected **Curtiss M. Everts, Jr.,** Chairman, **Vaughn Anderson,** Vice-Chairman, and **Herbert C. Clare,** USPHS, Secretary.

William M. Piatt, partner in the consulting engineering firm of Piatt and Davis, Durham, N. C., died recently following many active years in the sanitary engineering field. He was a Past-President of the North Carolina Member Assn. and a recipient of the Bedell Award (1949). As a member of the Federation Board of Control (1929–41) he served on the Finance and Executive Committees.

Vinton W. Bacon, Executive Secretary, Northwest Pulp and Paper Assn., has been honored as one of three winners of the 1956 Research Prizes of the American Society of Civil Engineers. The award to Bacon was made in recognition of achievements in applied research on waste water reclamation, pollution, and water quality.

The University of Kansas at Lawrence lost a long-time resident when the Kansas State Board of Health moved the Division of Sanitation, headed by **Dwight Metzler,** from Marvin Hall to the State Office Building in Topeka.

In Ohio, **Fred Waring,** Chief Sanitary Engineer, and his staff moved from the Ohio Departments Building to 101 North High St., in Columbus, Ohio.

Paul V. Hennessy, formerly of B-I-F Industries, has been appointed as a civil engineer with the Pipe Products Division of Gladding, McBean & Co. in its San Francisco, Calif., office.

Walter E. Gerdel, former superintendent of the Southerly Sewage Treatment Plant, Cleveland, Ohio, has been appointed Commissioner, Division of Sewage Disposal, Department of Public Utilities, Cleveland, succeeding **George E. Flower,** who retired earlier this year. Succeeding as superintendent of the Southerly plant is **Clyde E. Kirsch,** formerly assistant superintendent.

Dr. Abel Wolman, of Johns Hopkins University, was awarded an Honorary Degree of Doctor of Science by Drexel Institute of Technology. The presentation was made by **Francis S. Friel** (of Albright & Friel) Vice-Chairman of the Board of Trustees of Drexel.

Recent appointments of Chain Belt Co. include **William Sivyer** as Midwest and Southern Regional Manager, and **H. M. Weil,** Philadelphia, Pa., **D. P. Murrill,** Atlanta, Ga., and **F. R. Traylor,** Charlotte, N. C., as district sales managers.

G. E. Hauer, formerly Vice-President, American Well Works, is heading up a new industrial water and waste treatment department of Infilco Inc., Tucson, Ariz.

Dorr-Oliver recently broke ground for a new headquarters building in Stamford, Conn.

Jerome H. Svore, Chief Sanitary Engineer, North Dakota State Department of Health, has joined the U. S. Public Health Service as Chairman, Executive Committee, Columbia River Basin Inter-Agency Committee, Portland, Ore.

J. J. Horgan, former Sales Manager of Ralph B. Carter Company, Hackensack, N. J., has organized the Hydra-Numatic Sales Company of that city, as engineer sales representatives for several manufacturers.

Nicol MacNicol, Canadian municipal engineer, died recently. A Past-President (1946) of the Canadian Member Association, he served as Federation Director, 1953–55.

Reviews and Abstracts*

Spectrophotometric Determination of Microgram Quantities of Disodium Dihydrogen Ethylenediamine Tetra-acetate. By O. Menis, H. P. House and I. B. Rubin. *Anal. Chem.*, **28**, 1439 (1956).

The determination of disodium dihydrogen ethylenediamine tetra-acetate is carried out by adding 5.0 ml. of sample and 4.0 ml. of 0.25 per cent copper sulfate solution to a 25-ml. volumetric flask. The flask is filled with 0.1 M phosphate buffer adjusted to pH 11. After filtering, the concentration of copper EDTA complex is determined in a spectrophotometer at 250 mμ.

In samples with a concentration of 5 mg. per liter of EDTA, 5-cm. cells will permit a reproducibility of ±2 per cent. By using more concentrated reagents and a 20-ml. sample, a high degree of accuracy should be possible at even lower concentrations. Interference substances in samples of sewage or industrial waste must be considered. R. S. Ingols

Salthouse Storm-Water Pumping Station, Barrow-in-Furness. By J. C. Coutts and F. G. Frame. *Jour. Inst. Mun. Eng.*, **83**, 3, 101 (1956).

The existing conditions and problems of the sewerage of Barrow are described. The design and construction of a new pumping station with a total capacity of 240 c.f.s. is included in the description.

The existing system can discharge by gravity to the Sandgate Pumping Station which has a capacity of 38 c.f.s., or to sea at 63 c.f.s. Total discharge is 101 c.f.s. at low tide and 38 c.f.s. at high tide (the outfall is tide locked during high tide). The maximum theoretical D.W.F. in the sanitary sewer is 5.75 c.f.s. and storm-water flow is 178.25 c.f.s. Flows of 146 and 83 c.f.s. cause surcharging in the sewers at low and high tides, respectively.

Serious flooding has occurred in the low-lying area around Salthouse Bridge and adjoining areas. The flood problem at Salthouse has been considered by the local authorities for many years and the pumping station now under construction forms part of the scheme to solve the problem.

Peter C. G. Isaac

Quantitative Infrared Absorption Spectroscopy in Water Solution. By W. S. Potts, Jr. and N. Wright. *Anal. Chem.*, **28**, 1255 (1956).

Quantitative infrared absorption spectroscopy can be carried out in water solution by using a very thin absorption cell with barium fluoride windows. Useful transmittance in the region from 6.5 to 10 mμ. is obtained on a double-beam spectrometer with organic substances not soluble in the solvents normally used in the infrared spectroscope. R. S. Ingols

Microbiological Determination of Nitrate. By G. B. Garner, S. S. Baumstark, M. E. Muhrer, and W. H. Pfander. *Anal. Chem.*, **28**, 1589 (1956).

The microbiological determination of nitrate is quite specific in differentiating this substance from other forms of nitrogen. A 2.0-ml. sample is used, and inoculated with an organism which specifically reduces the nitrate to nitrite during a 5-hr. incubation with trypticase. At the end of this period, the total nitrite is determined colorimetrically at 550 mμ. with N(1-naphthyl)-ethylenediamine sulfanilic acid solution.

R. S. Ingols

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 4435 Wisconsin Ave., N.W., Washington 16, D. C.

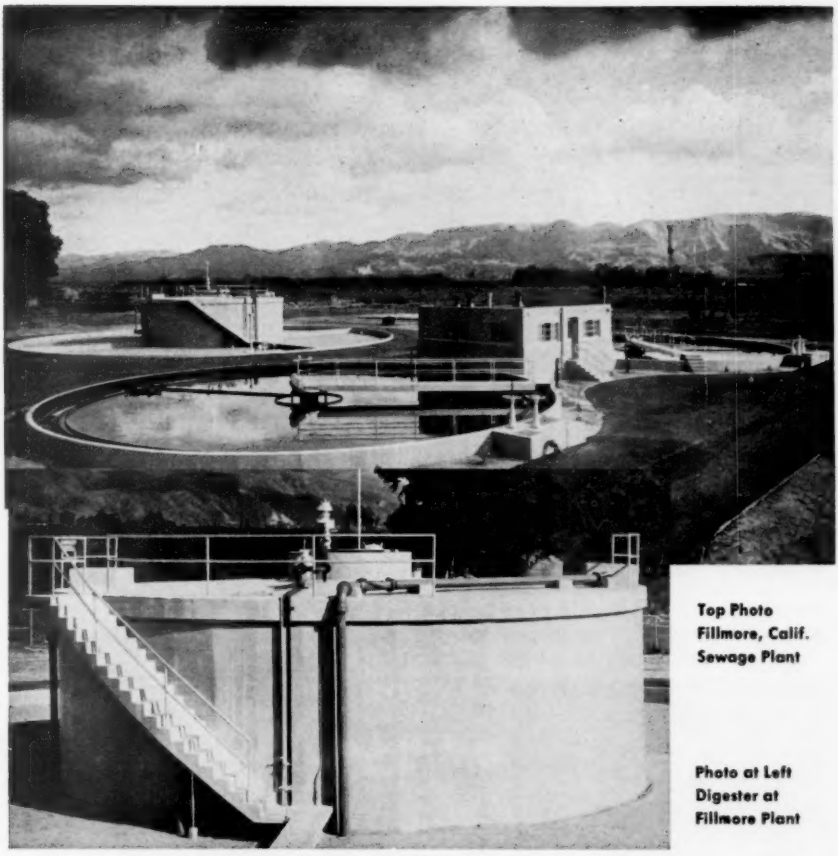

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Photo at Left
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Proceedings of Member Associations

FLORIDA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

Daytona Beach, Florida, was the site of the 1956 Annual Meeting of the Florida Sewage and Industrial Wastes Association, November 11–14, 1956. The meeting was held jointly with the Florida Section, AWWA.

The program of interest to sewage and industrial waste treatment personnel featured interesting panels on recent developments in industrial waste treatment and methods, and materials for sanitary sewer construction.

Technical papers of particular interest were:

"Anaerobic Treatment of Industrial Wastes," by A. M. Buswell, Research Professor of Chemistry, University of Florida, Gainesville, Fla.

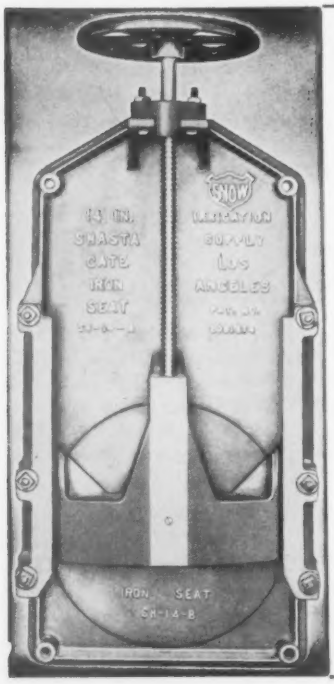
"Liquid Wastes Control in Phosphate Processing Plant, Part I, Triple Superphosphorus," by R. E. Tuttle, Manager, Technical Department, Bonnie Chemical Plant, International Minerals and Chemical Corp. "Part II, Phosphorus and Superphosphate," was presented by Randolph Specht, Research Engineer, American Agricultural Chemical Co.

"Oxidation Ponds," by D. F. Smallhorst, Texas State Department of Health, Austin, Texas.

"Sewage Treatment for Miami," by C. F. Wertz, Engineer, Miami, Fla.

"Waste Treatment in the Atomic Age," by K. S. Watson, Engineer, General Electric Co., Schenectady, N. Y.

(*Continued on page 336a*)



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Below: Tolleston Area: Chase Interceptor; 25th Street Interceptor
Engineer: Hurst-Roche, Inc., Hillsboro, Ill.
Contr.: Witter-Gaddis Constr. Co., Schererville, Ind.
Rhode Island Interceptor (not shown)
Engineer: Hurst-Roche, Inc.
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The second project, the Tolleston Area: Chase Interceptor; 25th Street Interceptor, was a $4 million job. The Chase Interceptor required about 2 miles of reinforced concrete sewer pipe from 60″ to 132″ in diameter. The 25th Street Interceptor required one and one-half miles of concrete pipe ranging from 24″ to 84″ in size.

The 132″ pipe was the largest ever installed in northwest Indiana. Both projects were financed by bond issues.

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Papers of general interest dealt with state and national water resources.

Federation Vice-President, K. S. Watson, presented the Arthur S. Bedell Award to John E. Kiker, Jr., Professor of Public Health Engineering, University of Florida, and the William D. Hatfield Award to Robert E. Simon, Superintendent, Orlando Sewage Treatment Plant. Business actions included consolidation of the newsletter activities with the activity of the Florida Water and Sewage Works Operators Association and the Florida Section, AWWA.

Officers elected for 1956–57 are as follows:

President: David B. Smith, Gainesville.

Vice-President: J. J. R. Bristow, Dunedin.

Secretary-Treasurer: Ralph H. Baker, Jr., Jacksonville.

M. E. DAWKINS,
Secretary-Treasurer

MARYLAND–DELAWARE WATER AND SEWAGE ASSOCIATION

The 30th Annual Conference of the Maryland-Delaware Water and Sewage Association was held at the Commander Hotel, Ocean City, Md., on May 23–24, 1957. Registration totaled slightly more than 150.

Featured papers of interest to sewage works personnel included:

"New Approach to Estuarine Pollution Investigations," by A. Joel Kaplovsky, Supervising Engineer, Delaware Water Pollution Commission, Dover, Del.

"Digester Cleaning at Washington, D. C.," by Hugh A. Schreiber, Superintendent, Sewage Treatment Plant, Washington, D. C.

"Evaluating Streams to Assimilate Sewage," By James R. McComas, Sanitary Engineer, Maryland State Department of Health, Baltimore, Md. This paper was discussed by J. W. O'Dell, District Engineer, U. S. Geological Survey, College Park, Md.

"Expansion and Rehabilitation of Sewage Treatment at Milford, Del.," by Robert J. Schatz, Gilbert Associates, Reading, Pa.

On the final day of the Conference there were panel discussions on the Federal Water Pollution Control Act and on the subject of automation.

Officers elected to serve for 1957–58 were:

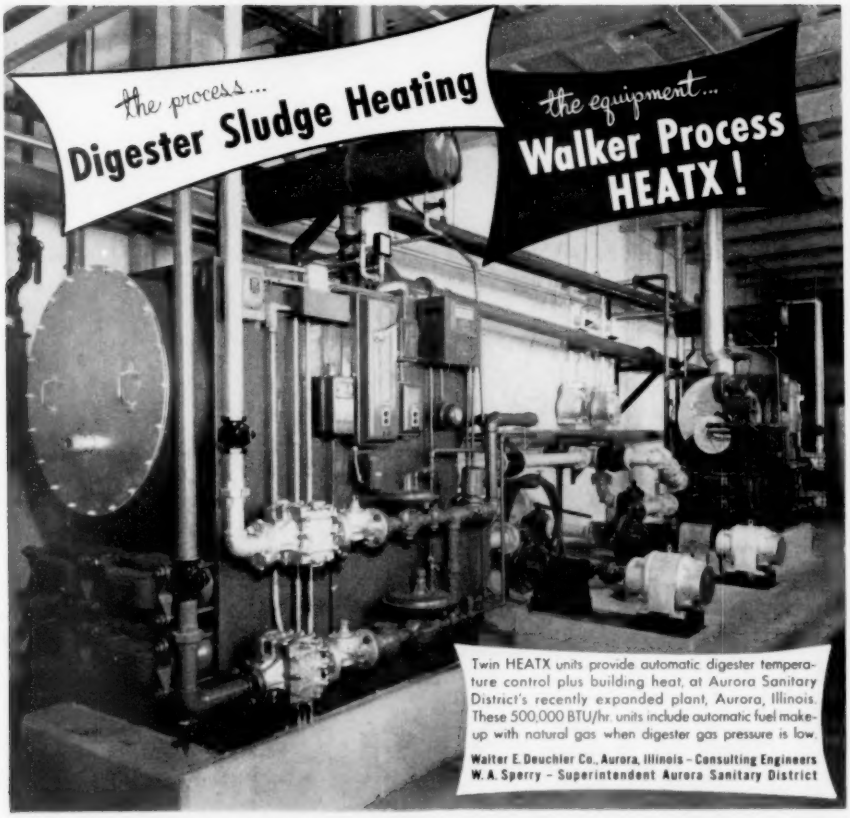
President: Robert H. Hartman, Frederick, Md.

1st Vice-President: Earl Craft, Wilmington, Del.

2nd Vice-President: Louis E. Otts, Jr., Riverdale, Md.

Secretary-Treasurer: W. M. Bingley, Baltimore, Md.

W. McLean Bingley,
Secretary-Treasurer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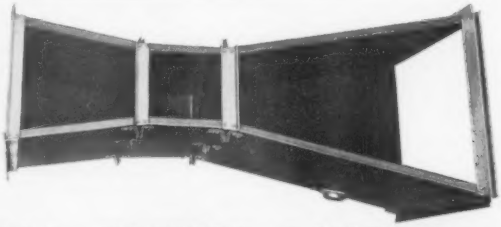

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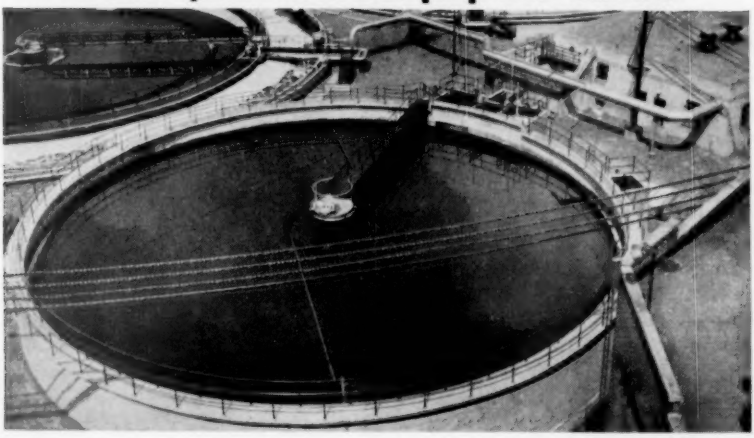

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Lab. Equipment—Laboratory equipment for use in the handling of radioactive materials in the laboratory is described in periodic releases.—The Atomic Center for Instruments and Equipment, Inc., 489 Fifth Ave., New York 17, N. Y.

Waterstop Joint—A new plastic expansion joint for use as a waterstop construction joint is described in literature entitled "Plasti-Grip."—Progress Unlimited Inc., 15 West 44th St., New York 36, N. Y.

Chlorine Vaporizer—Bulletin 132B describes a standard chlorine vaporizer system for converting liquid chlorine to dry vapor.—The Whitlock Manufacturing Co., West Hartford 10, Conn.

Cocks—Service, meter, and air cocks are described in the 12-page Bulletin V-605.—Meter and Valve Division, Rockwell Manufacturing Co., 400 North Lexington Ave., Pittsburgh 8, Pa.

Blowers—Newly revised Bulletin B-154A contains selection charts and other useful engineering information pertaining to the "Standardaire" blower, a compressor adaptable to either pressure or vacuum service.—Read Standard Corp., Blower Division, 370 Lexington Ave., New York 17, N. Y.

Smoke Density Recorder—Efficient incinerator operation can be aided by the use of equipment for measuring smoke density. Instrumentation Data Sheet No. 10.14-2a describes the "Brooke Smoke Density System," using Brown Recorders.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Portable Valve Seat Grinder—A portable valve seat grinder that can be operated by one man reportedly will reface valve seats, equal to new valve tolerances, while the valve is in the line.—Leavitt Machine Co., Orange, Mass.

Equipment Directory—A directory of standard products for materials handling and power transmission can be obtained by requesting Book 2653.—Link-Belt Co., Prudential Plaza, Chicago 1, Ill.

Chlorine Handling Equipment—Chlorine handling equipment such as liquid chlorine evaporators, valves and fittings, chlorine gas metering units, and detectors and alarm systems, are described in technical releases. Catalog File No. 50.100 series.—Wallace and Tiernan Inc., 25 Main St., Belleville 9, N. J.

Proportioning and Metering Equipment—Bulletin 403-1003 describes a new "ATI" proportioning and metering system.—Infilco Inc., Tucson, Ariz.

Meters and Controls—Measuring, transmitting, receiving, recording, and indicating instruments and control components for power and process applications are described in 8-page Bulletin G-15-1.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

Plastic Pipe—Bulletin No. CE-57 contains full details about the general and technical uses of flexible polyethylene plastic pipe. Items, prices, and other data are included.—Supplex Co., Garwood, N. J.

Equipment—Attractive, illustrated Catalog 905 describes the characteristics and applications of equipment for water, sewage, and industrial waste treatment.—The Jeffrey Manufacturing Co., Columbus 16, Ohio.

Rock Drills—A recent 12-page bulletin describes the design features and applications of Le Roi-Cleveland rock drills.—Le Roi Division, Westinghouse Air Brake Co., Milwaukee, Wis.

Plastic Tubing—Bulletin T-97 is a 28-page presentation of the applications and limitations of the various formulations of "Tygon" tubing.—The U. S. Stoneware Co., Akron 9, Ohio.

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(Continued through page 348a)

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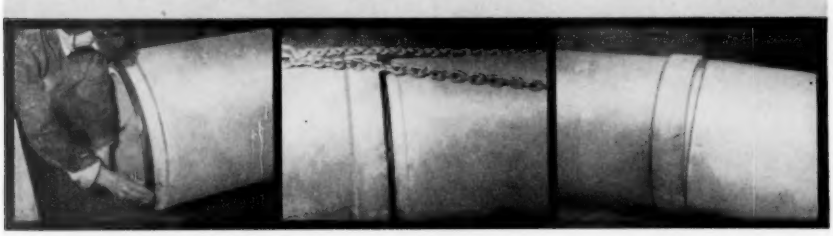

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